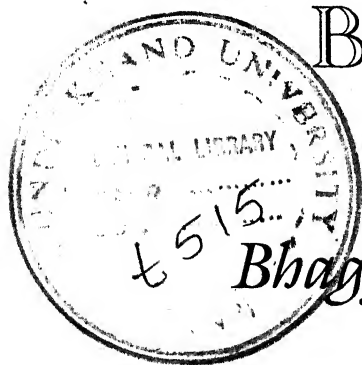


STUDIES ON SEED GERMINATION, GROWTH, PRODUCTIVITY,
MINERAL STATUS AND ENERGETICS OF SOME SELECTED
FOREST TREE SEEDLINGS IN BUNDELKHAND REGION



THESIS SUBMITTED TO
THE BUNDELKHAND UNIVERSITY, JHANSI
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Doctor of Philosophy
IN
BOTANY



BY

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2002

DECLARATION

I here by declare that the thesis entitled "Studies on seed germination, growth, productivity, mineral status and energetics of some selected forest tree seedlings in Bundelkhand region" being submitted to Bundelkhand University, Jhansi (U.P.) for the Degree of Doctor of Philosophy in Botany is an original piece of research work done by me and to the best of my knowledge and belief, is not substantially the same as one has been submitted for the degree or any other academic qualification at any other University or Examining Body in India or in any other country.

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Certificate

I have great pleasure in forwarding the thesis entitled, "Studies on seed germination, growth, productivity, mineral status and energetics of some selected forest tree seedlings in Bundelkhand region", submitted by Bhagya Laxmi Sengar, M.Sc., for award of the degree of Doctor of Philosophy in Botany of Bundelkhand University, Jhansi.

It is certified that Km. Bhagya Laxmi Sengar has completed the prescribed term of research work in the research laboratory of Department of this College under my guidance and supervision. The data embodied in the thesis are based on her own independent observations.

(U. N. Singh)

Guide/ supervisor

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(Bhagya Laxmi Sengar)

CONTENTS

	Page
Declaration	i
Supervisor's certificate	ii
Acknowledgement	iii
CHAPTER - I Introduction	1
„ - II Review of Literature	10
„ - III The Study Site	19
„ - IV Materials and Methods	31
(RESULT)	
„ - V Seed Germination	48
„ - VI Growth Analysis of Seedlings	56
„ - VII Biomass and Productivity	61
„ - VIII Energetics	79
„ - IX Mineral Status	91
„ - X Discussion	96
„ - XI Summary	109
References	

LIST OF TABLES

Table No.	Title
3.1	Climatic data of Aata (Orai), 1999-2000
3.2	Computation of water balance of Aata (Orai), 1999-2000
3.3	Physico-chemical characteristics of the study site
5.1	Germination percentage in dark and in different light conditions
5.2	Germination in different light and dark conditions in <u>A. lebbeek</u> (Analysis of variance)
5.3	Germination in different light and dark conditions in <u>D. sissoo</u> (Analysis of variance)
5.4	Germination in light and dark conditions in <u>T. arjuna</u> (Analysis of variance)
5.5	Germination percentage of different temperatures
5.6	Seed germination at different temperature in <u>A. lebbek</u> (Analysis of variance)
5.7	Seed germination at different temperature in <u>D. sissoo</u> (Analysis of variance)
5.8	Seed germination at different temperature in <u>T. arjuna</u> (Analysis of variance)
5.9	Germination percentage at different pH values
5.10	Germination of <u>A. lebbek</u> seed at different pH of the medium (Analysis of variance)
5.11	Germination of <u>D. sissoo</u> seed at different pH of the medium (Analysis of variance)
5.12	Germination of <u>T. arjuna</u> seed at different pH of the medium (Analysis of variance)
6.1	Net assimilation rate (mg/cm ² /month) at different ages of seedlings of <u>A. lebbek</u> , <u>D. sissoo</u> and <u>T. arjuna</u>

- 6.2 Relative growth rate (g/g/month) of seedlings of A. lebbek, D. sissoo and T. arjuna at different stages of their growth
- 6.3 Mean leaf weight ratio (cm²/g dry wt./month) of different seedlings of A. lebbek, D. sissoo and T. arjuna at different age.
- 7.1 Total standing crop biomass (g/plant) of different components of A. lebbek seedling
- 7.2 Total standing crop biomass (g/plant) of different components of D. sissoo seedling
- 7.3 Total standing crop biomass (g/plant) of different components of T. arjuna seedling
- 7.4 Percentage contribution of different component plant parts to the total plant biomass of A. lebbek seedling
- 7.5 Percentage contribution of different component plant parts to the total plant biomass of D. sissoo seedling
- 7.6 Percentage contribution of different component plant parts to the total plant biomass of T. arjuna seedling
- 7.7 Ratios of the total plant weight and component plant parts in A. lebbek seedling
- 7.8 Ratios of the total plant weight and component plant parts in D. sissoo seedling
- 7.9 Ratios of the total plant weight and component plant parts in T. arjuna seedling
- 7.10 Rate of production (g/plant/ day) of different component plant parts of A. lebbek seedling
- 7.11 Rate of production (g/plant/day) of different component plant parts of D. sissoo seedling
- 7.12 Rate of production (g/plant/day) of different component plant parts of T. arjuna seedling
- 7.13 Litter production in one year seedling of A. lebbek, D. sissoo and T. arjuna
- 7.14 Chlorophyll content in seedlings of A. lebbek, D. sissoo and T. arjuna at different stages of their growth

- 8.1 Energy content in fresh seeds of A. lebbek, D. sissoo and T. arjuna
- 8.2 Energy value (Cal/g dry wt.) of different fractional plant parts of A. lebbek seedling at different stages of growth
- 8.3 Energy value (Cal/g dry wt.) of different fractional plant parts of D. sissoo seedling at different stages of growth
- 8.4 Energy value (Cal/g dry wt.) of different fractional plant parts of T. arjuna seedling at different stages of growth
- 8.5 Energy contents (K Cal/plant) of different plant parts of A. lebbek seedling at various stages of growth
- 8.6 Energy contents (K Cal/plant) of different plant parts of D. sissoo seedling at various stages of growth
- 8.7 Energy contents (K Cal/plant) of different plant parts of T. arjuna seedling at various stages of growth
- 8.8 Energy conserving efficiency (%) of A. lebbek, D. sissoo and T. arjuna seedlings at different stages of growth
- 8.9 Caloric value and total amount of energy added to soil with the litterfall of A. lebbek, D. sissoo and T. arjuna seedlings
- 9.1 Total nitrogen and phosphorus content (mg/seed) of the seeds of A. lebbek, D. sissoo and T. arjuna
- 9.2 Accumulation of nitrogen (mg/plant) in component plant parts of different age group of A. lebbek, D. sissoo and T. arjuna seedling
- 9.3 Accumulation of phosphorus (mg/plant) in component plant parts of different age group of A. lebbek, D. sissoo and T. arjuna seedling
- 9.4 Total nitrogen and phosphorus content (mg/plant) of litter of A. lebbek, D. sissoo and T. arjuna seedlings
- 10.1 Comparative account of standing crop biomass and litterfall (g/plant) of A. lebbek, D. sissoo and T. arjuna seedlings upto the age of 12 months
- 10.2 Comparative account of energy trapped and released (K Cal/plant) by A. lebbek, D. sissoo and T. arjuna seedlings
- 10.3 Comparative account of nitrogen and phosphorus uptake, retention and release (mg/plant) in A. lebbek, D. sissoo and T. arjuna

LIST OF FIGURES

Fig No.	Title
3.1	Map showing the location of the study site.
3.2	Ombrothermic diagram of Orai (Aata) 1999-2000.
3.3	Water balance computation of Orai (Aata) 1999-2000.
5.1	Germination percentage in different light conditions and in complete darkness.
5.2	Germination percentage at different temperatures.
5.3	Germination percentage at different pH values.
6.1	Net assimilation ratio of different seedlings of <u>Albizzia lebbek</u> , <u>Dalbergia sissoo</u> and <u>Terminalia arjuna</u> at different age.
6.2	Relative growth rate of seedlings of <u>Albizzia lebbek</u> , <u>Dalbergia sissoo</u> and <u>Terminalia arjuna</u> at different stages of their growth.
6.3	Mean leaf weight ratio of seedlings of <u>Albizzia lebbek</u> , <u>Dalbergia sissoo</u> and <u>Terminalia arjuna</u> at different age.
7.1	Variation in biomass of different plant parts with increasing age of <u>Albizzia lebbek</u> seedling.
7.2	Variation in biomass of different plant parts with increasing age of <u>Dalbergia sissoo</u> seedling.
7.3	Variation in biomass of different plant parts with increasing age of <u>Terminalia arjuna</u> seedling.
7.4	Aboveground and underground plant biomass and rate of production at different age of seedlings of <u>Albizzia lebbek</u> , <u>Dalbergia sissoo</u> and <u>Terminalia arjuna</u> .
7.5	Percentage biomass in different components of different age of seedlings of <u>Albizzia lebbek</u> .
7.6	Percentage biomass in different components of different age of seedlings of <u>Dalbergia sissoo</u> .

- 7.7 Percentage biomass in different components of different age of seedlings of Terminalia arjuna.
- 7.8 Ratio of the different components weight to the total plant weight at different age of seedlings of Albizzia lebbek, Dalbergia sissoo and Terminalia arjuna .
- 7.9 Rate of production in different components at different age of seedlings of Albizzia lebbek, Dalbergia sissoo and Terminalia arjuna .
- 7.10 Chlorophyll content in seedlings of Albizzia lebbek, Dalbergia sissoo and Terminalia arjuna at different age.
- 8.1 Energy value of different fractional plant parts at different age of seedlings of Albizzia lebbek.
- 8.2 Energy value of different fractional plant parts at different age of seedlings of Dalbergia sissoo.
- 8.3 Energy value of different fractional plant parts at different age of seedlings of Terminalia arjuna.
- 9.1 Total nitrogen and phosphorus in different components of different age of Albizzia lebbek seedling.
- 9.2 Total nitrogen and phosphorus in different components of different age of Dalbergia sissoo seedling.
- 9.3 Total nitrogen and phosphorus in different components of different age of Terminalia arjuna seedling.
- 11.1 Schematic representation of standing state of biomass, energy and minerals in different components at different age (months) of seedlings of Albizzia lebbek.
N and P represents nitrogen and phosphorus respectively.
- 11.2 Schematic representation of standing state of biomass, energy and minerals in different components at different age (months) of seedlings of Dalbergia sissoo.
N and p represents nitrogen and phosphorus respectively.
- 11.3 Schematic representation of standing state of biomass, energy and minerals in different components at different age (months) of seedlings of Terminalia arjuna.
N and P represents nitrogen and phosphorus respectively.

CHAPTER - I

INTRODUCTION

INTRODUCTION

Forest are essential for human survival and impose vital impact on climate, soil erosion and floods. Forests have contributed to the prosperity of our Nation as a whole and they are the sources of human history, Godly gifts and are faithful friends of mankind.

Trees are vitally and intriguingly connected with the life of mankind. The poet and the musician, artist and the writer, primitive people and the civilised societies, all have come under their spell.

The Indians have been worshipping the trees since the time immemorial for several reasons viz., fulfillment of one's desire, attainment of wisdom, propitiation of evil spirit and cure of diseases etc. They are also regarded as the symbol of the unity of life.

In spite of such tradition of mutual relationships between man and trees, his attitude towards them has taken a turn in the reverse direction. The very materialistic approach in resorting to environmental degradation has made the man vainfully MASTER over nature rather than trying to establish bonds of friendship with it.

Animal and trees are the co-ordinators of nature but due to unlimited exploitation, the balance of the life animals and plants has been disturbed greatly. At present there are about a quarter of million plant species in the world. If man continues to exploit the natural resources at such a tremendous rate, one sixth of the plant population could be extinct before the

year 2050. Many of them would even disappear without being properly identified and without their benefit to the human race (Redfern, 1986). The extinction of plants would act as a slow poisoning to the nature which in turn would become helpless to save the mankind.

A recent study by the United Nation's Commission for Asia and the Pacific, has reported the destruction of tropical forests in South-East Asia and India as, "One of the greatest tragedies of our times." The study further says, that the degradation of forests in Asia is a classic example of third-world problems which they must not ignore. The report also states in terrorem that the disappearance of irreparable forests also means the loss of the earth's 'GREEN LUNGS' with incalculable consequences for the ecological imbalance of our planet (Bahuguna, 1986).

Nature will protect and nurture the man so long as he reciprocates with it. Indiscriminate destruction of Nature's bounty is bound to cause grave consequences. Though, ruthless felling of the forest trees has caused nudity to the environment, yet proved as a necessary evil for human survival.

Hence, only forest can save mankind from the impending disaster. The creation of forests will undoubtedly prove the best ecological antidote against the anthropogenic contamination of the environment.

CURRENT NEEDS

Once considered to be rich in forests, India is now specified on

the map of the world as ' A DEFICIT ZONE; Of Late Nation is now aware to the supreme need of forests and forestry. Importance of Forest Ecology is being realised more and more by Inter-Governmental and Governmental agencies because of the environmental problems created by the depletion of resources, soil erosion, degradation and frequent ecological backlashes in the form of floods, famine, disease, pollution and other such calamities.

Although much ecology of the forest is known but the behaviour of germination and seedling growths which affect the developmental stages of the ecosystem has been least studied. It is not unusual to find a good crop of seedlings in the forest. Hence, it would be of great interest to understand their contribution to the productive structure as a whole.

Germination and growth behaviour vis-a-vis mineral status of seedling population may assume significant role in the process of recruitment to the forest during succession. This phenomenon appears to be complex and the first step of understanding is to reveal the features of the seedling of a few dominant tree species.

Germination of seed is an important phase in the ecological life history of any species in that it determines the potential of that species to spread in, given favourable conditions for establishment.

Germination is the outcome of the interaction of various environmental factors with the intrinsic capabilities of the seeds. The initial step in germination is the reactivation of systems conserved during the seed maturation period. Arousing a dry seed to start growth into a new plant involves

four groups of processes as :

- (1) The imbibition of water
- (2) The formation of enzyme systems,
- (3) The commencement of growth and radicle emergence and finally,
- (4) The growth of seedling with the characteristics features associated with the subterranean plant upto the time of emergence from the soil.

The environment has a profound effect on the germination behaviour, which is brought about in two ways. The environment prevailing during seed formation and the environment existing during seed germination (Kaller, 1972 ; Mayer and Shain, 1974). Thus germination process is controlled by a system of interacting reactions of the environmental factors. However, in no case the information is available about the exact mechanism by which the germination behaviour is determined by the environment. The major conditions of life or growth necessary for germination are viz., access to water, a suitable range of temperatures, Oxygen pressure, different concentrations of inorganic salts, inhibitors and for some seeds the exposure to light. It is suggested that the environmental factors control germination by acting on specific sites of metabolic sequences (Mayer and Shain, 1974).

According to Sweet and Wareing (1968) "while forestry as a science is concerned largely with growth rates of the crop as a whole, there is none the less, a demand both the physiologist and the tree breeder for an increased understanding of the factors that determine the growth rates of

individual plants both as seedling and as adult trees." As it is difficult to carry out the experiments on mature tree, most of investigations on growth rate have been made on seedlings.

The growth analysis separates the effects of environment on dry matter production per unit leaf area (N A R) from its effect on production of leaf area. The growth expressed as dry matter accumulation depends mainly on the efficiency on solar energy utilization, by the tree or net diurnal efficiency of assimilation per unit of assimilatory surface.

All organisms require a source of potential energy in order to be able to survive and work. The ultimate source of energy is the solar radiation. This energy is trapped by green plants, the producers, and is converted into chemical energy which is stored in the form of various organic substances in the growing tissue.

The primary productivity is of special significance in ecology. It is the energy fixed by plant that supports all life and only the green plant has the power to transform the energy of sun into potential energy by photosynthesis. It constitutes the source of food for all heterotrophs. The total amount of chemical energy stored by the plant per unit area of leaf per unit time is referred to as the gross primary production. Gross primary production minus respiration, therefore, represents the food energy potentially available to heterotrophs and is designated "Net primary production" which may be called simply as production.

When production is measured as dry weight it includes some

mineral salts incorporated into the products of photosynthesis. According to Newbould (1967) if ash content is estimated and excluded, from the gain in weight then only it should be specified as organic production. In the present investigation the term production is used as referring to net production of dry matter with ash.

Dry matter production is the key function in ecological and sociological life of plant (Boysen and Jensen, 1932; Monsi and Sacki, 1953). According to Lieth (1968), the determination of dry matter production by the plants always constitutes the basis for further studies in production ecology.

The role of energy fixation by green plants, though, affected by several factors, is also dependent to some extent of the chlorophyll content. According to Odum (1970) measurement of photosynthetic pigments have been widely used to estimate the amount of active photosynthetic machinery present in ecological systems and to infer something about its activities.

Energy of the sunlight is the single most important aspect of the abiotic environment that determines, to a large extent (about 90%) the plant growth and yield. Knowledge of the energy content of plants is necessary to understand the energy dynamics of individual population in the ecosystem. Park (1946) also said that probably the most important ultimate objective of ecology is an understanding of community structure and function.

Energy conserving efficiency (E.C.E.) of the green plants depends upon the intensity of solar radiation and other atmospheric conditions.

The subject of ecological energetics is relatively new but there

has been rapid and important developments in the field during the recent years (Phillipson, 1966).

The concentration, distribution and amount of different nutrients present in different components of an ecosystem vary greatly. The nutrient differences normally reflect differences in the nature and amount of organic matter present. The production of plant material by photosynthesis results in the uptake of plant nutrients from the soil, from precipitation and from the atmosphere. According to Ovington and Madgwick (1959b) the estimation of essential mineral elements both in plant and soil system provides a basis to evaluate the productivity of the ecosystem. In an ecosystem energy fixation and dry matter production of the primary producers depend greatly upon the supply of the biogenic salts (Odum, 1959). In the forest ecosystems soil is the main source of the necessary mineral elements. The interrelationship of the plant and soil can be studied by quantitative estimation of mineral contents. This also gives an idea of the magnitude of production breakdown and accumulation of organic matter.

The primary type of biological cycle, which may be called as mineral cycle, includes uptake and retention of elements from the soil and atmosphere by the living organism and the return of elements to the soil with the annual litterfall and death of the plant parts (Rodin and Bazilevic, 1967)

The process of energy capture by primary producers depends upon the availability of mineral nutrients (Wassink, 1968). The green assimilating organs play the major role in the uptake of mineral elements and

account for 70 to 80 % of the uptake in forest. Infact, plants stand as an intermediary between the non-living and the living world. Thus, the study of mineral cycling in nature will be an important feature of the study of terrestrial ecosystem. This will include major as well as minor elements. This will also involve studies on nitrogen fixation accomplished by non-leguminous plant. According to Dwivedi (1970) a deficient supply of nitrogen leads to the development of small plants and under such condition they are not capable of converting primary assimilates into protoplasm. Thus, a sufficiently rapid increase in the quantity of photosynthetic tissue is impeded. Similarly, phosphorus plays important role in energy transfer process (role of ADP and ATP). It is also constituent of nucleic acids and phospholipids. Thus, it helps in the synthesis of protein and the richest energy compounds i.e. fat.

Thus, mineral elements have direct impact on the rate of organic matter production and hence in the functioning of the ecosystem. This aspect has drawn the attention of several workers. According to Whittaker (1971) analysis of nutrient elements of plant tissue may be combined with measurements of biomass and net production of the tissues.

Foregoing in the literature clearly indicates that the measurement of gross primary production or energy trapping capacity of primary production which is useful for determining the different components of ecosystem, net energy consering efficiency, loss of energy during respiration of plants and energy or dry matter removed by herbivores (Milner and Hughes, 1968; Dwivedi, 1970) and cycling of phosphorus in relation to energy conservation

of plant have not received much attention. Thus, the present work on seed germination, seedling growth, productivity, energetics and mineral status of three forest tree seedlings is to be viewed in a borader context of ecosystem problems.

CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Seed germination in a well programmed process controlled by both the internal and external factors. Seeds do not resume physiological activity until they imbibe a certain amount of water (Come and Tissaoui, 1973)

Water uptake by seed is prerequisite of germination. It is assumed that the failure of living seeds to germinate, or to delay in the germination is due to insufficient or delayed hydration of the seed (Mathur, 1965). Different duration of imbibition affect the germinative capacity of forest tree seeds (Yadav and Mishra, 1962). A continuous water stress inhibited seed germination, almost completely at 5 bar water potential in winged beans (Kuchhar and Garg, 1983). In five cultivars of Carthamus tinctorious, the germination percentage declined as the water stress become higher (Ojha and Sinha, 1986).

Magnum opus has been done as regards the study of germination in different seeds (Bahuguna et al., 1987-88; Banik, 1987; Dahral, 1985 and Maithani et al., 1987). Seedcoats have long been considered to be a kind of barrier to water absorption. Such type of impermeability of the seedcoats to water can be over come by increasing the absorbtive power of the inner tissues, which is generally brought about by prechilling or by scarification.

Recently effect of different methods of scarification on seed germination has been studied in various plants (Babeley and Kandya, 1985a,b; Bahuguna et al., 1988; Bakked and Goncalvis, 1984; Gill et al., 1986; Rai et

al., 1988; Vasistha and Soni, 1988 and Verma and Tondon, 1984).

Mechanical scarification and pretreatment with conc. H_2SO_4 and HNO_3 stimulated germination in Acacia farnesiana (Gill et al., 1986). Sulphuric acid treatment has positive effect on germination of Trema politoria seeds (Vasistha and Soni, 1988). In Ficus bengha lensis, F. glomerata, F. mysorensis and F. religiosa soaking of seeds for 10 minutes in hot water at $60^\circ C$ gave the highest germination percentage (Rai et al., 1988). For best germination in teak, soaking of seeds for 48 hours in water and then followed by an alternative drying and soaking (12 hours each) for 21 days is recommended (Ngulube, 1988). Seeds of Acacia catechu treated with conc. Sulphuric acid for 10 and 15 minutes gave better results (Babeley and Kandy a, 1985b). Bhandri ad Bhandari (1993) studied the influence of irradiated medium on radiosensitivity of Dalbergia sissoo Roxb. Extensive research on seed size effect on various aspects of plant growth pertaining to field crops has been carried out with positive correlation between seed size and vigour of plants. This information is in an infant stage on many of the forest tree species (Chauhan and Raina, 1988; Ghosh et al., 1976; Gupta et al., 1983; Harper and Obeid, 1967; Kandya, 1978; Naugriya and Pathak, 1983; Shukla and Ramakrishnan, 1981 and Thapliyal, 1986). Generally large seeds were found to germinate fast and more completely Krishnaswamy et al., 1982; Pathak et al., 1980; Roy and Pathak, 1983; Wood et al., 1977; Gera et al. (1999) studied seed sources variation in germination in ten indigenous population of Dalbergia sissoo Roxb.

Seed germination may be inhibited by the presence of specific

substances in the soil derived from plants of the same or of different species (Mandava, 1985; Mc Donough, 1977; Parihar, 1980; Tukey, 1969; and Whittaker, 1970; Malic and Patil (1995) conducted germination studies in Terminalia arjuna and similarly Totey et al. (1997) made an observation of the effect of Rhizobium biofertilizer on seed germination of seeds of Dalbergia sissoo.

The beneficial effect of soaking the seeds with growth regulator (photo-hormones) and other chemicals has been reported by a great number of workers (Bisht and Fuloria, 1988; Chatterjee, 1960; Datta and Nanda, 1986; Ghose and Chatterjee, 1976; Gupta, 1975; Sahai et al., 1980, and Thimann; 1972). In the seeds of several species inhibitory effects of Indol-Acetic Acid (IAA) has also been reported (Naik, 1954; Sharma and Govil, 1987 and Sircan, 1963).

Srivastava et al. (1996) studied seed characters, productive behaviour and reproductive capacity in Terminalia species. Similarly Sahai and Sahai (1994) and Mishra and mishra (1991) made an observation on the effect of laboratory and field condition [in M.P.] on germination and seedling survival in Dalbergia sissoo Roxb.

Mithani et al. (1988) studied the effect of size of containers and different soil needs on the germination behaviour and growth of Acacia nitotica, Albizzia procera and Dalbergia sissoo. Gere et al. (2002) made an observation on seed trait variation in Dalbergia sissoo Roxb.

Under any given set of conditions the daily rate of dry matter

production (RGR) can be determined by three parameters of growth: Net assimilation rate (NAR), ratio of total assimilatory surface to total plant weight (mean leaf weight ratio i.e. MLWR) and the duration of the productive period within the annual cycle (Blackman, 1968; Pollard and Wareing, 1965). Normally it is preferred to measure the net assimilation rate on leaf area basis (Friend et al., 1965).

The technique of growth analysis, which renders it possible to determine these parameter has frequently been used in the study of agricultural crop (Watson, 1952). There have been few reports on the applications of this method for woody plants (Rutter, 1957; Jarvis and jarvis, 1964; Brix, 1967; Newhouse and Madgwick, 1968; Pollard and Wareing, 1968; Sweet and Wareing 1968; Blackman, 1968;). Palani et al.(1996) studied the effect of per-sowing on growth attributes of Albizzia lebbek (L.) Benth.

Evidence for the effect of plant age on classical growth analysis attributes is conflicting. Many experiments have indicated that there were no significant trends in NAR with time during the vegetative phase (Heatch, 1937); Blackman and Wilson, 1951). Since these studies were conducted in natural conditions, the effects of seasonal trends in environmental factors were difficult to distinguish from the effect of age.

The estimation of dry matter production in different environmental and edaphic conditions with different plants has been made by means of harvest method (Odum, 1958 a,b; Ovington, 1956,57,62; Ovington, and Madgwich, 1959; Whittaker, 1961; Misra et al., 1967; Kira and shidei 1967

Rodin and Bazilevic 1966, 68; Golley et al. 1960) When measured through harvest method, the net production is represented by the total dry weight of herbage at the end of growing season (Hadley and Kiechafer, 1963) or by the sum total of the maximum weights attained by individual species (Odum, 1960; Golley, 1965). Ovington, et al. (1963) estimated the annual productivity from the difference between recorded maximum weight and lowest over wintering weight of plant biomass. Singh (1967) and Chaudhari (1967) have used the short term harvest method at Varanasi and found comparable results.

Lieth (1965), Woodwell and Bourdeau (1965), Woodwell and Whittaker (1968), Newbould (1967), Attiwill and Ovington (1968) have compared the validity of different techniques used in the determination of forest biomass. In India, the studies on dry matter production by Shorea robusta under plantation conditions (Ramam, 1966) and in Rihand forest area (Misra et al., 1967) were initiated as pilot investigations for the proposed IBP/PT/India project. But a very few published data are available on the dry matter production and production rate of seedlings. Therefore, the present study deals with the growth and dry matter production of tree seedlings.

Kumar and Tokey (1996) studied variation in seed germination and juvenile growth of twelve provinces of Albizia lebbak. Patel and Singh (1996) observed the dynamics of growth and biomass production in some tree species under nursery condition.

Much emphasis has recently been given to the relationship between the chlorophyll content and dry matter production (Broughiam, 1960;

Whittaker and Gartive, 1962). Bray (1960), Lieth (1965), Medina and Lieth (1964) have shown a direct correlation between the amount of chlorophyll and dry matter production. Ovington and Lawrence (1967), however, found that the relationship between chlorophyll content and the net production of organic matter by plants varies with the season. Indeed, the chlorophyll estimation has been regarded as a measure of the size of the photosynthetic systems and has been recommended as a part of the investigations related to IBP (Newbould, 1967). That is why leaf area and the total chlorophyll content of a community serve as reliable index of its primary productivity.

In earlier reports definite caloric contents were used to determine the energy status of particular trophic level. However, it was soon realised that the calorific values differ considerably with the season, plant species, plant parts and vegetation of different ecological communities.

Pioneer workers in the field of energetics are Odum and Odum (1955) who initiated research in this direction and studied the transformation of energy in the coral reef community at Florida. Later Odum (1957) presented the trophic structure of silver springs and marine turtle grass community at Florida. Following them a number of other workers from different parts of the world have entered in this field of study and have collected the data for various types of biological communities (Richman, 1958; Kamel, 1958; Patten, 1959; Slobodkin and Richman, 1960; Golley, 1960, 61; Bngleman, 1961; Comita and Schindler, 1963 and Davier, 1963).

Energy values of different biological materials have been

estimated by Golley et al. (1962), Ovington (1961, 63), Ovington and Heitkamp (1960) and Biliss (1962). Weigert and Evans (1964) estimated the calorific values, energy content and energy flow in old field community U.S.A. and William (1996) on a California range.

Phillipson (1966) was of opinion "that" Ecological energetics is the study of energy transformation within an ecosystem. Laboratory studies with algal suspension have been shown (Williams and Joseph, 1970) that plant can convert about 10 per cent of the incident solar radiation into the food energy but in practice it is found that under the best agriculture methods, crops may convert 5.4% of the total incident solar radiation for a short period and no more than 2% over a entire growing period (Wassink, 1968). Energy content of both, the incoming radiation and the plant biomass is expressed in caloric (Cal.) or Kilo Calorie (K.Cal.. = 10^3 Cal.) OR Joule (1 Cal. = 4.186 J)

Recently Odum (1967, 70) has given a new approach to the ecological energetics by deriving various models applicable to the different types of ecosystem.

In India, the calorific values and energy content of terrestrial and aquatic communities have been estimated by Chaudhari, 1967; Singh, 1969; Dwivedi, 1970; Singh, 1972 at Varanasi. Gupta 1972) had been made similar study at Gyanpur, Jain (1971) at Sagar, Mall and Singh (1971) at Ratlam, Naik (1973) at Ambikapur, Das (1974) and Asthana (1974) at Gorakhpur, Trivedi (1976) and Gupta (1976) at Jhansi and Srivastava (1980) at Orai.

Recently Katewa and Tiagi (1990) determined energy value of

three promising grasses of Udaipur District, Bewa and Singh (1991) at Shimla, Pandya (1991) at Katch and Gupta (1993) in Bundelkhand region Orai (Jalaun) studied different aspects of energy i.e. structure, energy conserving efficiency and energy flow.

In terrestrial plants phosphorus cycling has been studied, by estimating the productivity and phosphorus content of the crop, by Sonn, 1960; Smironov and Gorodentseva, 1958; and Mina, 1955; in spruce, birch and oak trees respectively. Importance of inorganic nutrients in governing the growth, organic productivity and distribution of plant species has been well recognised by various workers (Specht, 1963); Bazilevic and Rodin, 1964). The nutrient uptake, estimates and their calculation for different age of forest growth are reviewed by Rennie (1955). Mina (1955), Ovington (1959,62), Ovington and Madgwick (1959 a,b), Cole et al. (1967) studied mineral cycling in temperate forest. Tropical forests have been investigated in this regard by Moore, 1959; Nye, 1961; Bazilevic and Rodin, 1966; Odum, 1970; Golley, 1971 b,c.

In India Misra, 1970; Desh Bandhu, 1971; and sharma, 1971 have also measured the uptake, retention and release of many mineral elements in dry deciduous forest (IBP/Pt site) at Varanasi by estimating annual dry matter production and its elemental contents.

According to Hewitt (1963) the leaves which are the primary site for trapping solar energy, are distorted in their shape under inadequate supply of phosphorus. This consequently reduces the energy trapping efficiency i.e. the rate of dry matter production of plant (Aslander, 1958 and Russel, 1963).

Phosphorus also play an extramely important role in a variety of reaction in seed and seedlings. The various phosphate sugars and nucleotides are closely linked with the energy producing precess in the cell during germination. Similarly in the deficient supply of nitrogen, plants remain small and under such condition they are not capable of converting primary assimilates into protoplasm.

In India some valuable data on nutrient uptake and turnover in trees and seedlings at the new Forest. Dehra Dun have been made available (Seth et al., 1961, 63; Kaul and Srivastava, 1967, 68, 69; Misra and Bajpai 1971, Desh Bandhu, 1971; and Sharma, 1971; have investigated the same aspect in the dry edciduous forest of Varanasi. Similiar studies have been made by Sengar (1983) in Shisham plantations in Bundelkhand region at Orai.

CHAPTER - III

THE STUDY SITE

THE STUDY SITE

LOCATION AND TOPOGRAPHY

The study area selected for present investigation is situated in the premises of Aata Forest Nursery, Orai at lat. $25^{\circ} 59' N$, long. $79^{\circ} 37' E$ and is about 125 m above mean sea level in northern part of the Bundelkhand region. The study site is at a distance of about 5 km towards east of Orai, District Jalaun (U.P.) as depicted in Fig. 3.1.

The study site extending over an area of one hectare was fully protected from all the types of biotic interferences.

Bundelkhand is suitable for good growth of grasses and fodder crops has a central position in the county. The site for investigation is a part of land bounded by Yamuna river in north, Betwa river in south and Madhya Pradesh in the West.

Besides southern marginal area, the topography of this region is of undulating type. Trans-Yamuna plain is another name of Bundelkhand plain which is topographically divisible into three east-west running belts i.e. southern, northern and central belts. Orai is located in northern belt and confined along the bank of river Yamuna in the form of high ground which represents the level of ancient flood plain but at present is badly cut in to ravines.

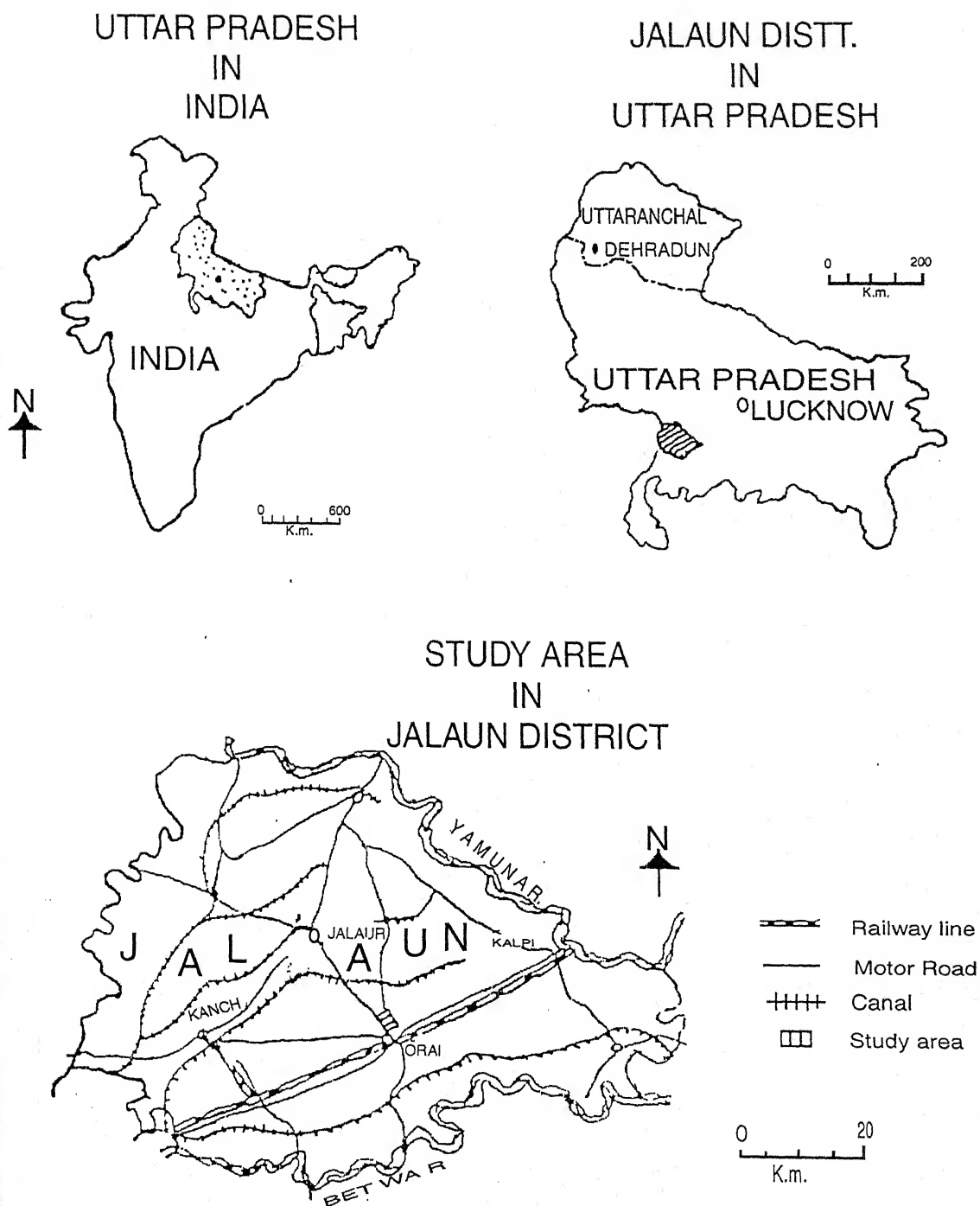


FIG. 3.1 SHOWING THE LOCATION OF STUDY SITE

LITHOLOGY (GEOLOGY)

Sand stones, lime stones and shales are the common rocks. The special features of immense geographical interest in this region are quartz, reefs and dolomite dykes which are long and narrow with serrated ridges. The geological system is covered in the north-east by Ganga-Yamuna alluvial deposits in the form of an 'embayment'.

NATURAL VEGETATION

The region is ecologically degraded and the original vegetation has almost been removed for inhabitation and cultivation. Shrubs and grasses represent the secondary growth throughout the region. Babool is the principal type of Acacia. Khair is the common tree but not much utilized for grazing.

Albizia procera (Siris), Anogeissus pendula (Dhawana), Tectona grandis (Teak), Butea monosperma (Dhak), Dalbergia sissoo (Shisham), Acacia catechu (Khair), A. nilotica (Babool), Zizyphus mauritiana (Bair), Carissa carandus (Karondha), Capparis aphylla (Kareel), Balanites aegyptica (Hingota). Albizia lebbek (Black Siris) are the main contributors in the natural vegetation of this region.

CLIMATE

The climate of Bundelkhand region is typically dry sub-humid and has a distinct seasonality. It is characterised by three seasons.

- i) Rainy season (July-October): It is warm and wet.

- ii) Winter season (November-February): It is cool and dry.
- iii) Summer season (March-June): It is hot and dry.

The climatic records of Orai are summarized in Table 3.1.

The mean annual temperature of Orai is 24.8°C but mean monthly values considerably vary from their annual means (14.5 to 35.5°C) and consequently their ranges are high. On occasional nights, temperature may fall down to a lowest minimum of 2°C . The intensity of the summer season increases with a very hot westerly dust laden winds called 'Loo', which usually blow throughout May and June and the temperature continuously increases upto a highest maximum of 45°C in May.

Total annual precipitation comes to about 1186.8 mm of which 90% falls between July to October i.e. during wet summer when temperature fluctuates around 30°C . The on set of monsoon takes place during the end of June with maximum rainfall during July and August some shallow westerly depressions cause occasional winter rains which take place by the end of December upto the end of February or March. Winter accounts for only 2% of the annual rainfall.

With respect to wind, because of intensity of rains and temperature variation will depend upon the direction of wind, it blows over the area running from Bay of Bengal obliquely south-east and north-west direction in July. In winter month the wind direction changes from north-west to south-east. During summer the wind is westerly with a maximum velocity of 5.3 km per hour in May. Percentage relative humidity (mean monthly) of the area very

Table 3.1: Climatic data of Aata (Orai), 1999-2000

Months	Temperature °C				% Relative humidity			Wind velocity Km/hr Mean month.	Rainfall (mm) Monthly	Incident Energy K cal/m ² x 10 ³ / day
	Mean max.	Mean min	Mean month.		Mean morn.	Mean even.	Mean month.			
March	30.7	13.6	22.0		50.6	38.6	44.6	3.0	19.3	5.28
April	38.0	20.1	29.0		37.3	18.0	27.6	3.5	1.0	5.59
May	44.9	26.2	35.5		25.4	19.0	22.2	5.3	-	5.81
June	39.2	25.0	32.1		50.0	40.6	45.3	4.4	99.2	5.40
July	34.0	24.1	29.0		78.0	67.0	72.0	2.0	615	5.13
August	32.8	23.9	28.8		73.7	72.5	73.1	2.8	194.8	4.56
September	31.9	23.5	27.7		66.5	66.7	66.6	2.9	169.7	4.54
October	32.1	20.0	26.0		60.0	52.0	56.0	1.8	69.0	4.56
November	31.1	15.0	23.0		50.0	38.0	44.0	1.7	3.4	4.01
December	24.5	7.6	16.0		57.5	43.8	50.6	2.0	5.0	3.67
January	23.5	5.5	14.5		51.8	45.7	48.7	2.0	8.4	3.76
February	22.4	6.8	14.6		44.3	46.3	45.3	3.0	2.0	4.44

from 22.2 to 73%.

According to Gaussen (1960) the effectiveness of climatic factors like temperature, precipitation and length of dry period can be understood in a better way by means of Ombrothermic diagram (Fig.3.2). This is done by bringing out the elements on a graph, on the abscissa are marked months, on ordinates of the left the temperature and to right the rainfall.

For tropical regions, where the mean monthly temperature is about 25°C, rainfall under 50 mm, would classify a month as dry. Thus, the ombrothermic conditions of the area revealed 8 dry months and 4 wet months during the year.

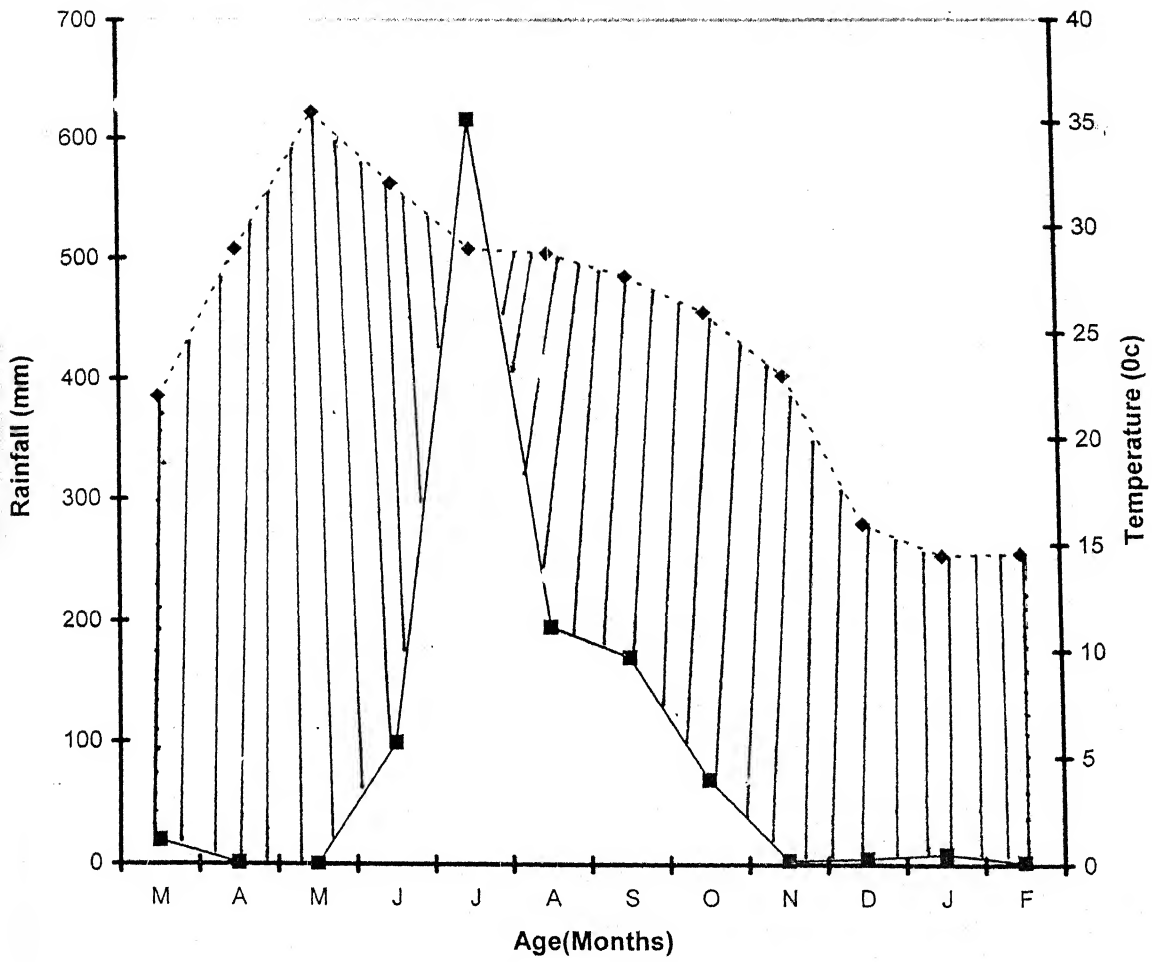
SOLAR RADIATION

Solar radiation was not recorded at study area (Orai). Therefore the mean value of Patana (Lat. 25° 35' N) and Jodhpur (Lat. 26° 15' N) stations has been considered here for calculation of total incident solar energy because the geographical situation of Aata Forest Nursery (Orai), the study area (Lat. 25° 59' N) is approximately in between the above two situations.

ECOCLIMATE

Climate of an area in relation to growth of vegetation is measured in the form of precipitation, wind velocity, humidity, temperature etc. Any single factor of climate does not give a clear picture about the exact climate of an area in relation to the growth of vegetation. According to Subramanyan (1958)

Fig. 3.2 -Ombrothermic diagram of Orai (Aata) 1999-2000.



it is not possible to say that a climate is moist or dry from precipitation alone. These measurements also does not provide the water need of a given region is the total amount of water required for full use of vegetation including transpiration as well as direct evaporation from soil-surface. Thus, the combined evaporation from the soil surface and transpiration from plant surface called 'Evapo-transpiration'; represents the transport of water from the earth back to the atmosphere, the reverse of precipitation. This atmospheric circulation is a part of the hydrological cycle. The numerical estimate of this part of hydrological cycle in space and time leads to the concept of 'Water Balance'. Water Balance is a balance between the income of water from precipitation and the loss of water by evapo-transpiration, surface run-off and infiltration. The water balance computation equation after Thornthwaite is:

$$\begin{aligned} \text{Ppt} &= \text{Potential evapo-transpiration-deficit} + \text{surplus} \\ &= \text{Storage charge (amount of water temporarily stored in soil)} \end{aligned}$$

Potential evapo-transpiration (PE) as proposed by Thornthwaite (1948) is define as the amount of water that would evaporate and transpire from a vegetation of soil moisture were always available in sufficient amount for optimum use. It is a climatic balance since precipitation and evapo-transpiration are active factors of climate.

The whole computation of water balance is carried on by tables and nomograms as proposed by Thornthwaite (1948) and Thornthwaite and Mather (1955). Subramanyan (1958-1959) has published a series of papers on this aspect in India. Pandeya et al. has computed the water balance of

atleast 8 stations of western India in 1973 including Jhansi station of Bundelkhand region.

In present study the water balance of Orai station for Aata Forest Nursery is computed on the above pattern as per the method proposed by Thornthwaite and Mather (1955) presented in Table 3.2 It is evident from the table that actual evapo-transpiration (AE) was governed by the amount of water available for plant growth and soil moisture storage. In the rainy season, when there was sufficient water for plant growth and soil moisture storage, rates of actual evapo-transpiration were found maximum. By the end of Rainy season (October) when precipitation was less than PE, a decrease in the rate of AE was recorded and this decrease was continued till January/February. When soil moisture is at field capacity or above i.e. in the growing period (July to September) actual and potential transpiration are the same, and all precipitation above the water need is counted as surplus (S). The annual value of water surplus comes to 21 cm. This surplus water is totally spent in soil moisture recharge. When precipitation falls below the water need i.e. PE or AE becomes less than PE (October to June), this difference is the water deficit (D). The annual value of deficit is 38.6 cm. The major deficit is reported in April and May. In the graph (Fig.3.3) monthly course of PE and AE is compared with the precipitation showing clearly the S and D region.

The net water surplus (S-D) for the whole year, the negative value is obtained (-17.59cm).

On the basis of moisture index (Im) value (-1.70) the area of the

Table 3.2: Computation of water Balance of Aata (Orai), 1999-2000

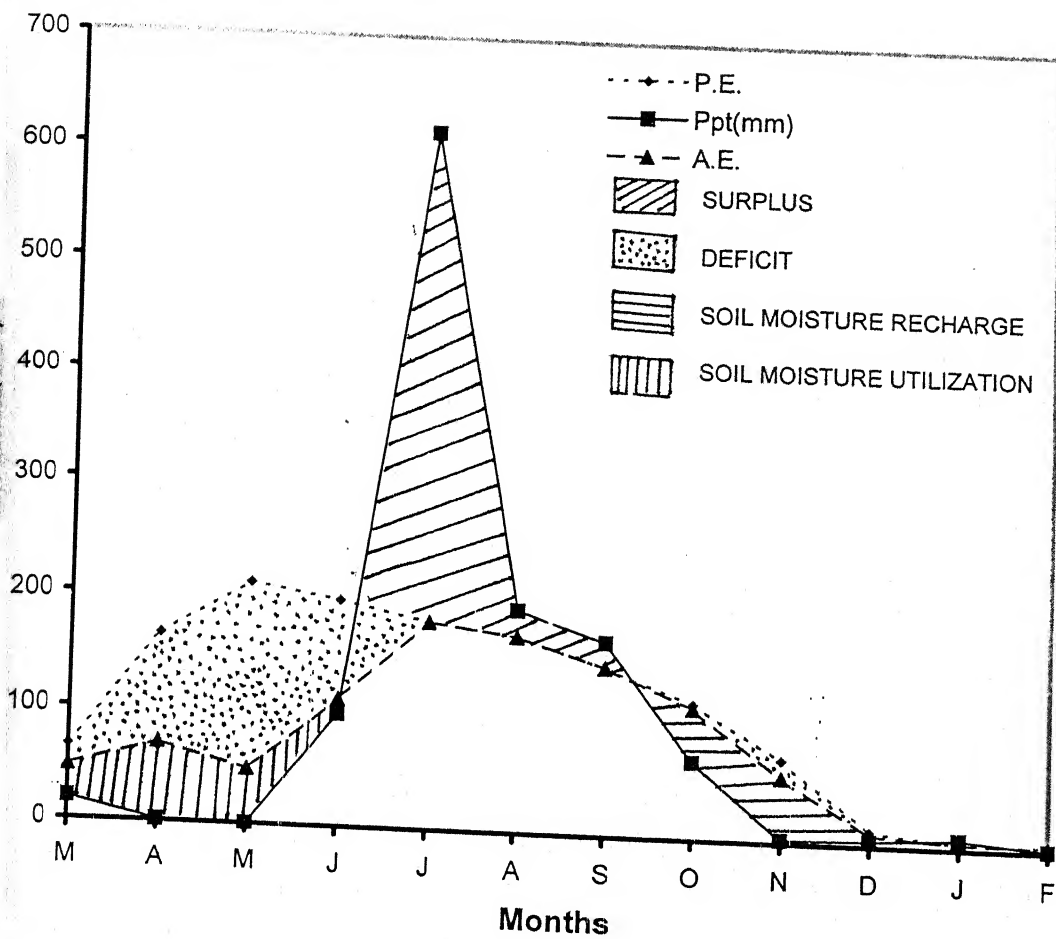
Lat. N 250 59' 30"N Long. E 790 37' 30" Ht. 125m.

	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
T ^o C	22.0	29.0	35.5	32.1	29.0	28.8	27.7	26.0	23.0	16.0	14.5	14.6
i	9.42	14.32	19.45	16.70	14.32	14.17	13.36	12.13	10.08	5.82	5.01	5.07
U.P.E.	6.4	15.54	18.37	17.35	15.54	15.38	14.53	12.0	8.0	1.4	4.5	0.6
P.E.	66	165	211	198	182	172	148	119	73	13	5	5.3
Ppt (mm)	19.3	1.0	0	99.2	615	194.8	169.7	69	3.4	5.0	8.4	2.0
P - P.E. = Δ	-46.7	-164	-211	-98.8	+433	+22.8	+21.7	-50	-69.6	-8	+3.4	-3.3
Σ Δ	-181.0	-345	-556	-654.8	+433	+455.8	+477.5	-50	-119.6	-127.6	-131.0	-134.3
St	-163	-94	-46	-33	300	300	300	-254	-200	-195	-193	-191
Δ St	-28	-69	-48	-13	+267	0	0	-46	-54	-5	-2	-2
A.E.	47.3	70	48	112.2	182	172	148	115	57.4	10	5	4
W.D.	18.7	95	163	85.8	0	0	0	4	15.6	3	0	1.3
W.S.	0	0	0	0	166	22.8	21.7	0	0	0	0	0
R.O.	0	0	0	0	83	11.4	10.35	0	0	0	0	0

T^oC = Mean monthly temperature
 i = Heat index
 U.P.E. = Unadjusted Potential Evapotranspiration
 P.E. = Potential Evapotranspiration
 Ppt = Monthly Precipitation
 Σ Δ = Summation Data (Potential water loss)
 S.T. = Storage
 W.D. = Deficit
 W.S. = Surplus
 R.O. = Run off
 A.E. = Actual Evapotranspiration

Fig. 3.3 - Water balance computation of Orai (Aata) 1999-2000.

Rainfall (mm)



study can be classified as dry sub-humid (C_1) which is further classified on the basis of thermal efficiency i.e. PE (135.7cm) as second megathermal (A_2). The value of summer concentration of thermal efficiency (SCTE) i.e. 43.5 comes to 'a2' symbol which clearly indicates that lower SCTE value means high temperature uniformly month after month. SCTE may be defined as the rates of thermal efficiency for the three summer months to the total annual efficiency expressed as percentage. Thus, ecoclimate formula of the study area comes to $C1A_2 a_2 s$. Here the small s indicates summer water efficiency.

The various climatic indices worked out are:

Potential Evapo-transpiration	(PE) = 135.7 cm	= 1357 mm
Humidity Index	(Ih) = $S/PE \times 100$	= 15.5
Aridity Index	(Ia) = $D/PE \times 100$	= 28.46
Moisture Index	(Im) = $Ih - 0.6 \times Ia$	= -1.07
Summer Concentration of Thermal Efficiency (SCTE)		= 43.5

Total annual precipitation is 1186.8 mm and because of large amount of radiation energy received (Table 3.1), the PE is always higher than the precipitation except in the month of July, August and September and to some extent in January when it almost compensates each other.

SOIL

The soil of Bundelkhand region is considerably variable in soil types, their colour, texture, depth etc. Soil survey and soil work reports for

Bundelkhand region have been published by Agrawal and Mehrotra (1952) and Mehrotra and Gangwar (1970). Ray Chaudhary *et al* . (1963) have also given an exhaustive account of Bundelkhand soil. These reports and works revealed that the soil of this region can be categorised in two groups on the basis of red and black soil.

Red soil is a light soil and black soil is a heavy soil. There are two groups in each soil, Red soil consists of 'Rakar' and 'Paruva' on one hand and the black soil comprises 'Mar' and 'Kabar' on the other hand.

Another classification grouped the soil of this region into (1) upland and (2) low land soil and (3) riverain soil. Formation of these soils takes place partly by transportation agencies, chiefly by streams.

Jalaun district in its low lying areas consists of black soil and in its both groups i.e. Mar and Kabar, Mar is calcareous with kankar, so it is friable and aerated but Kabar is highly diffused.

On the basis of soil analysis the physicochemical characteristics of the study area area given as under in details (Table3.3)

The colour of/the soil was pale brown as Value, Chroma and Hue found to be 10 YR, 6/3.

The texture of the soil showed as loam i.e. medium textured with 37.19% coarse sand, 6.45% fine sand, 27.15% silt and 31.15% clay. Soil pH Indicated that it was slightly alkaline in reaction i.e. pH 7.60, 7.70 and 7.60 at 0-10, 10-20 and 20-30 cm depth respectively. (Table3.3)

Soil samples were taken from different depths 0-10, 10-20 and

Table 3.3: Physico-chemical characteristics of the study site

Physico-chemical characters	Depth in cm		
	0-10	10-20	20-30
pH	7.60	7.70	7.70
Water holding capacity (%)	42.69	43.62	43.74
*Moisture (%)	17.09	18.65	20.63
Prosity (%)	51.25	52.08	49.16
Nitrogen (%)	0.05	0.04	0.03
Available Phosphorus	0.019	0.013	0.006
Organic Carbon	0.65	0.55	0.49
C/N rattoo	13.0	13.75	16.33

* Based on the average of soil sample collected at monthly sampling periods.

20-30 cm) for the estimation of water holding capacity (W.H.C.), moisture percentage, organic carbon percentage and nitrogen content. Result showed that W.H.C. and moisture percentage increased with depth. The average W.H.C. of three depths was 43.35%. Average annual moisture percentage was 18.79 with minimum value of 12.80%.

Organic carbon percentage at different depths of soil i.e. 0-10, 10-20 and 20-30 cm was 0.65, 0.55 and 0.49% respectively.

Ratio of organic carbon and nitrogen (C/N) was 13.0, 13.75 and 16.33 for different soil depths i.e. 0-10, 10-20 and 20-30 cm respectively. (Table 3.3)

CHAPTER - IV

MATERIALS AND METHODS

MATERIALS AND METHODS

Materials and methods are discussed below for each observation separately in detail.

4.1 FENCING OF STUDY SITE

Although the Forest Nursery, Aata was already fenced but the experimental site was further fenced by barbed wire to avoid all types of biotic interferences.

4.2 CLIMATIC PARAMETERS

To describe the climatic conditions of the study site during study period the meteorological data i.e. temperature, humidity, wind velocity and rainfall of Orai was collected from the meteorological observatory, Civil Aerodrome, Lucknow. The solar radiation data has been obtained from meteorological observatory, Pune.

4.3 SOIL ANALYSIS

Before analysis, each soil sample taken from the study site was air dried, powdered and sieved through 2 mm mesh size and then taken into the soil testing laboratory, Department of Agriculture, Government of Uttar Pradesh, Orai and Research Laboratory, D.V. Postgraduate College, Orai.

A. Physical Properties of Soil

i) Soil Texture:

To find out the soil texture about 5 g soil sample was slowly moistened to make a paste which forms the basis to determine the texture type by field touch method. Further it is confirmed by mechanical analysis based on proportion of different sized particles.

ii) Soil Colour:

Soil colour was determined by taking the dry powdered soil on a white paper and comparison with Munsell's colour chart.

iii) Soil Moisture:

The soil moisture was determined at different intervals from transplantation to the last harvesting. Layerwise soil sampling from 0-10, 10-20 and 20-30 cm depth was done at each harvest. The soil samples were collected with the help of screw auger in aluminium boxes specially made for the purpose. After taking the fresh weight the samples were dried in oven at 105°C for 48-72 hours to obtain constant weight. The soil moisture was computed using the following formula:

$$M = \frac{W_w - W_d}{W_d} \times 100$$

Where,

M = Moisture percentage

W_w = Weight of wet soil in g

W_d = Weight of dry soil in g

iv) Soil Porosity:

Scrapped the soil surface to a flat plain. A straight walled pit (10 X 10 X 10 cm) was dug out and thus the soil removed was collected in a polythene. The soil sample was oven dried at 105°C and weighed. To find out the volume of the pit, a measuring cylinder was filled by sand with the help of a funnel. The pit in turn filled completely by dropping sand from the measuring cylinder through the same funnel. The volume of the sand needed to fill the pit was noted. Porosity of the soil was calculated as under:

$$\text{Percent of pore space} = \frac{2.6 - D}{2.6} \times 100$$

Where,

D = Oven dry weight of soil / Volume of pit

2.6 = Approximate specific gravity of the soil particles.

v) Water Holding Capacity:

To obtain water holding capacity of the soil, keen Raczkowdis boxes (Piper, 1944) were used. The boxes were circular and made up of brass with numerous perforation in the bottom. An average amount of the water retained by one circular whatman's filter paper No.1 has been estimated by weighing 5 moistened filter paper and the sum weight of those filter papers divided by 5. The circular filter paper then placed in each box. The empty boxes with moistened paper were weighed. The boxes then filled by soil sample and levelled to boxes with the help of glass slide. Then the boxes were placed on the stand and water was filled in the space, made for the purpose on the stand, till the saturation of the soil. The boxes with saturated soil were kept

over-night. Next day weights of boxes with moisture saturated soil were taken and placed in the oven under 105°C for 48-72 hours. Oven dried soil was reweighed. To calculate the water holding capacity, the values were substituted in the formula given below:

$$\text{WHC} = \frac{b-c-d}{c-a} \times 100$$

Where,

a = weight of unfilled brass box + Filter paper

b = Weight of box + water saturated soil (over-night)

c = Weight of box + oven dried soil

d = average amount of water retained by one filter paper.

B. Chemical Properties of Soil:

i) Soil pH:

Elico pHmeter composed of glass electrode and reference electrode was used in the estimation of pH of the soil. Before the use of the apparatus, the glass electrode was activated by putting it into N/10 HCl solution for 24 hours. The reference electrode was filled with saturated KCl solution. The pH meter was allowed to warm up by switching on sometime earlier of its use. The accuracy and sensitivity of pH meter was checked by using solutions of known pH made by dissolving the buffer tablets of different pH values (Standardisation).

The 20 g air dry soil was dissolved in a 40 ml of flat bottom flask. It was stirred well with glass rod and thereafter, electrode assembly dipped into

it. The needle of pH meter indicated the pH value. The electrode assembly was carefully cleared with soft paper or towel before measuring the next sample.

ii) Soil Organic Matter:

Organic matter was determined by Walkley and Black's rapid titration method (Piper, 1944). In this process one gram of soil powder was taken into 500 ml Erlenmeyer flask and 10 ml normal potassium dichromate solution was added in flask. Now 20 ml conc. H_2SO_4 was poured rapidly directing the stream into the solution. The solution in the flask was immediately swirled Vigorously for 1 minute and the flask was put on asbestos sheet for 30 minutes. Afterwards 200 ml of water, 10 ml of phosphoric acid and 0.5% solution of diphenyl amine indicator (about 2 ml) was added in the flask. The solution became dark blue. The flask solution was titrated by adding ferrous ammonium sulphate (F.A.S.) drop by drop until the colour flashed to light green. This process was repeated for blank. The percentage organic carbon was calculated as follows:

$$\% \text{ Organic carbon} = B - S \times 0.003 \times 100$$

Where,

B = F.A.S. for Blank

S = F.A.S. for soil sample

0.003 = amount of carbon used for 1 ml of pot. dichromate

$$\% \text{ Organic matter} = B - S \times 0.003 \times 100 \times 1.724$$

(Because organic matter consist of 58% carbon or $1.724 = 100 / 58$)

iii) Soil Nitrogen:

Soil Nitrogen was determined by micro-kjeldahl method following Jackson (1958). The digestion of the material was done prior to the titration in sulphuric acid and using CuSO_4 , K_2SO_4 and Selenium powder as catalyst. After digestion, the solution was extracted with distilled water and the volume was made up. The extract was distilled with strong NaOH in the Markham's distillation unit and the distilled NH_3 was collected in dilute H_2SO_4 mixed with bromocresol green-methyl red indicator. The boric acid was blank titrated with 0.05 N HCl and the percentage of nitrogen (N) was calculated following the formula given by Jackson (1958).

$$\% \text{ N} = (\text{T}-\text{B}) \times \text{N} \times 1.4 / \text{S}$$

Where,

T = Sample titration, ml standard acid

B = Blank titration, ml standard acid

N = Normality of standard acid

S = Sample weight g

The total nitrogen was determined by the modified Kjeldahl method (A.O.A.C., 1965).

iv) Soil Phosphorus (Available):

An aliquot of the extract solution of the soil was taken in a 50 ml volumetric flask and pH was adjusted at 3 using Na_2CO_3 and dinitrophenol as an indicator. In this solution sulphomolybdic and molybdophosphoric acids were added. Blue colour was developed after adding a few drops of

chlorostanous acid in the test solution and within the specific time, transmission was read photometrically at 660 nm wave length (Jackson, 1958)

v) C/N Ratio:

The percentage of soil organic carbon and nitrogen already estimated has been used to calculate the C/N ration i.e. total amount of carbon by nitrogen.

(PLANT MATERIALS)

4.4 SEED COLLECTION

The seeds of Albizzia lebbeck (Siris) Wre collected in the month of Feruary and those of Dalbergia sissoo (Shisham) and Terminalia anjuna (Arjun) in the month of March, 1998 all from the neighbouring forests. The seeds were stored in stoppered glass bottles.

The trees grow in a mixed dry deciduous forest in Bundelkhand region. The forest is situated at lat. 25° 59, N, long 79° 37' East and about 125 m above mean sea level.

4.5 PHENOLOGICAL STUDIES

i) *Albizzia lebbeck*:

A. lebbeck is a plant of deciduous forest. It is extended from low-himalayan hill range in north to Tamilnadu and Kerala in south. It can grow in varieties of soils. It can be grown even in usar land. It requires high light

intensity. It does not prefer shade. The average height of the plant is 8-12 m but in favourable condition the plant can grow upto 30 m long and stem circumference 3m.

It starts flowering in April and may as a result the whole plant is covered with yellow and white fragrant flowers. Flowers are found in bunches which are dense and globular. This plant is deciduous. Leaf fall starts in November.

The plant pods are 10-25 cm long and 2.5-4 cm wide. It is flat in shape and straw coloured. Ripening of fruits occur in December and January. Pods are attached to the mother plant for a long time i.e. upto the reflow spring. Each pod contains 6-12 seeds and 1 kg contains approximately 12,300 seeds which are dark gray in colour.

The timber of this tree is costly and the heart wood is brown (Badami) in colour and durable. Seasoning is easy. The timber is used for a number of works i.e. furnitures, Ply, bullock-cart etc. The plant is useful for grazing land and road side plantation. It can be grown in dry and saline soil. In eroded area it is grown to check soil erosion.

ii) Dalbergia sissoo:

D. sissoo is a species found in tropical region where temperature varies from - 4 to 49°C and rainfall 750 to 4500 mm. This plant is found naturally in sub-himalayan region at the height of 1500 m and extending over the Gangetic plain. It is also known as riverain plant. This plant normally prefer a sandy moist land and no water logging.

It is often planted in sandy dunes of Rajasthan. In favourable condition and region the plant can grow upto 25 m long and more than 2 m in circumference.

D. sissoo is generally used as road side plantation though it is not good shading plant. It is a fast growing species. The leaves are compound and light in colour. The leaves are 2.5-7.5 cm long and 2-5 cm wide. The shape is rounded or oval and the tip acute.

Leaffall occurs in November and December. The plant requires high light intensity. It is a hard and strong plant. There is no effect of frost on the plant. It is a good coppicing plant and new plant are produced by root sucker.

Flowering starts from March and April as a result the whole plant is covered with white-yellow flowers. The pod is 5-8 cm long and ripening start at the commence of winter and the colour of the pods changes into brown which is the best period to collect the seed. The pods are flat and each pod contains 1-3 seeds. One kg pods contains about 50,000 seeds which are brown-red in colour.

iii) *Terminalia arjuna*:

T. arjuna is commonly found in river's bank, eroded land, dry river and canals. Its distribution is extended upto sub-Himalayan region. It is a big and good looking plant and to a some extent ever green. Its small branches are hanging downwards. In Uttar Pradesh, it is extensively planted on road side where water logging occurs for 4 of 5 months. It can be produced even in a mdium level of usar land. This plant can be used for seri-culture, therefore,

it is good for social-forestry programme and is being extensively used. This plant can grow well in the region where rainfall varies from 750 - 1800 mm and temperature from 0-48°C. It is the average shade producing plant. It is good coppicing plant and can tolerate lopping as well. It produces flower starting from April to July. Fruiting closely follows flowering. Ripening of fruit takes place in between February to May.

The fruit of T. arjuna 4.0 to 6.0 cm long, dark brown in colour and having one seed in each fruit. Fruit wall is very hard and five forked.

4.6 EXPERIMENTAL SITE

Culture experiments were conducted at about 5 km, away from Orai city in forest nursery Aata. The forest nursery is situated at about 5 km east of Orai city (25° 59' N latitude and 79° 37' E, longitude), approximately 125m above mean sea level.

4.7 EXPERIMENTAL DESIGN

The experiments were performed mainly as follows:

Healthy seeds of Albizia lebbek, Dalbergia sisso and Terminalia arjuna were sown in pot on 24th February, 1999 after the protrusion of the radicle, they were transplanted in the beds of the forest nursery, Aata. All these species were planted in rows spaced at 25cm across and downwards. Regular weeding was done at the intervals of fifteen days to avoid any interspecific competitions.

4.8 SEED GERMINATION

Before starting germination experiments, viability of the seeds was tested by the T.T.C. reaction (Mrsra, 1968). The seeds were soaked in distilled water for 24 hours and fifty of them were thereafter kept between two moist filter paper in each petriplate. Some of the petriplates were transferred to a light proof wooden box for dark treatment and the rest were placed in a chamber lighted with fluorescent tubes. The desired colour of light i.e. blue and red was obtained by the use of celluphane paper (Pandey, 1968) of respective colours. Buffer solution for seven different pH values were prepared according to Pandeya et al . (1968). Germination was tried in each of the seven pH solution with three replicates for each buffer. Except for the temperature treatment all the experiments were conducted at room temperature. High and low temperature incubators were used for the study of effect of temperature on germination.

Emergence of radicle through seed coat was considered as the criterion of germination. After recording the germination daily the sprouted seeds were removed from the petridishes. The percentage germination for a period of ten days was taken as final reading.

4.9 GROWTH ANALYSIS OF SEEDLINGS

For the sake of uniformity in growth, seeds collected from only one tree were used. After the seed germination, the seedlings were transplanted to forest Nursery. The sampling interval was one month. Ten

replicates were taken under study till their age was less than four months. After this age only five replicates were used. The observations were taken in the very first week on every month during the year 1999-2000. The sampling consisted of complete dug out plants. All plant parts were hand separated into root, stem and leaf fractions. Root and stem were washed before they were subjected to drying at about 80°C for nearly 48 hours (Ovington and Madgwick, 1959). Woody parts with more than 1 cm diameter were split into small sections before they were subjected to drying. Before separating the plants into fractions, leaves were plucked and their area was measured. The leaf area was determined with the help of planimeter in case of Terminalia arjuna. In Dalbergia sissoo and Albizia lebbek the same has been determined by weight method described by Watson (1958).

Due to labour problems it was not practicable to sample on identical dates in successive months. This might lead to minor error for comparative studies.

Formulation of growth analysis:

The following formula were used for calculating different aspects of growth:

$$\text{Relative growth rate (RGR)} = \frac{\log W_2 - \log W_1}{T_2 - T_1}$$

$$\text{Net assimilation rate (NAR)} = \frac{W_2 - W_1}{L_2 - L_1} \times \frac{\log L_2 - \log L_1}{t_2 - t_1}$$

$$\text{Mean leaf weight ratio (MLWR)} = \frac{W_2 - W_1}{\log L_2 - \log L_1} \times \frac{\log W_2 - \log W_1}{W_2 - W_1}$$

Where,

W_1 = dry weight at time t_1

W_2 = dry weight at time t_2

L_1 = leaf area at time t_1

L_2 = leaf area at time t_2

The merits and demerits of the various methods of calculating growth analysis parameters have been examined by a number of workers (e.g. Williams, 1946). Hence, it will not be necessary to do it here. It should be noted, however, that the formulae used here give mean RGR and NAR values for the period between two harvests.

4.10 BIOMASS AND PRODUCTIVITY

To estimate the standing crop biomass and the productivity of the primary producers the well known harvest method Odum, 1960; Ovington, 1962; Newbould, 1967; was followed. According to Woodwell and Whittaker (1968) the systematic harvest of the standing on land and the technique is specially well adopted to communities that are small in stature.

The plants were dug out from the nursery bed. The litter falling in the month of January and February was collected like that did by Odum (1960). It included all the dead materials on the surface of the ground. The plants were washed. The root, stem and leaves were separated. They were kept for drying at 80°C for 48 hours. After oven drying the material was weighed. The average total weight of root, stem and leaves indicates the standing crop per

plant per month. The productivity for the month was evaluated by subtracting the weight of biomass from that of the subsequent month.

4.11 CHLOROPHYLL ESTIMATION

The leaves were plucked from the seedling at monthly intervals in the morning hours (6.00 A.M. - 9.00 A.M.). Dicus of 1.5 cm diameter were cut from both the sides of midrib of many leaves throughout the leaf length with the help of a cork borer. To avoid any photooxidation the leaves, leaf discs and chlorophyll solution were kept in dark at 10-20° ~~o~~ in a refrigerator. The chlorophyll estimations were made by spectrophotometric method given by Arnoun (1949).

For the extraction of chlorophyll three replicates of 0.25 g of leaf discs were taken. In case of Dalbergia sissoo and Albizia lebbeck 0.25 g of leaflets were taken for each determination. The discs were grinded separately in acetone: alcohol (4:1 by volume) in a glass mortar. The solution was centrifuged at approximately 3000 r.p.m. The supernatant (chlorophyll solution) was decanted from the residue. This chlorophyll solution was made upto 50 ml in each case. The absorbance of solution was determined at 663 and 645 m μ on Beckmann spectrophotometer. The check reading at 652 m μ was also carried out. The value of total chlorophyll was calculated using the formula of Arnon (1949).

For estimation of dry weight 0.25 g by weight of the discs in ten replicates were kept in oven for drying at 80°C for nearly 24 hours, after taking

the fresh weight. The amount of chlorophyll is expressed as mg per gram dry weight of the leaves.

4.12 DETERMINATION OF CALORIC VALUES

The caloric values were determined from samples, collected in different months of the year 1999-2000. The samples were dried for 48 hours at nearly 80°C (Lieth, 1968) and then reduced to powder in electric grinder. Before subjecting to caloric analysis the plant material from each category, was compressed into pellets (about a gram in weight) and kept in desiccator. Three replicates were made for each sample. The caloric values were determined by igniting the pellets of the plant material in oxygen bomb calorimeter (Parr. Instrument Co., U.S.A.) in the presence of oxygen (at 12.5 lb pressure).

Calculation :

The following formula has been followed.

$$E = \frac{W_1(t_2 - t_1) + W_2(t_2 - t_1)}{W} \quad \text{Calories/g dry wt.}$$

Where,

W_1 = Water equivalent of bomb vessel (g)

W_2 = Weight of water in gram

W = Weight of pellet of plant material (g)

E = Caloric values of plant material

t_1 = Initial temperature (°C)

t_2 = Final temperature (°C)

The energy content in the standing crop was calculated with the help of per gram value. Energy accumulation in different plant parts of standing crop biomass has been determined. Energy content in fresh seeds of A. lebbeck, D. sissoo and T. arjuna which moved to the growing parts of the seedling is estimated by the formula given by Troine et al. (1924).

$$\text{Energy efficiency} = \frac{E}{E_1 - E_2} \times 100$$

Where,

E = Energy value of the seedling

E_1 = Energy value of the seed at the start

E_2 = Energy value of the seed residue

4 13 ENERGY CONSERVING EFFICIENCY

Efficiency is the ration of output (calories captured by vegetation) to input (solar radiation) in an unit area over a certain length of time.

In the present investigation the percentage of the energy conserving efficiency of seedlings of different age groups of A. lebbeck, D. sissoo and T. arjuna has been calculated by the following formula:

$$\text{Energy conserving efficiency} = \frac{\text{Net production} \times t}{1/2 \text{ Solar radiation on the canopy} \times t} \times 100$$

Where,

t = time

The net dry matter reduction per plant as obtained during different

growth period has been converted into energy values (K cal / plant) by multiplying them with caloric value of the plant material.

In this investigation only half of the solar radiation has been considered for calculating efficiency because approximately 50 percent of the total radiation (that in ultra violet and infreared portion of the spectrum) is not usable in plant photosynthesis (Daubenmire, 1947; Nichiporovich, 1967 and Terrin et al., 1957). The data of solar radiation (Cal / cm² / day) for Orai was taken from the department of meteorology, Poona (Chapter III, Table 1).

4.14 GRAPHICAL REPRESENTATION OF DATA

The data obtained on various aspects under the investigation have suitably been depicted through graphs, histograms and curves wherever necessary to illustrate the experimental findings.

CHAPTER - V

SEED GERMINATION

SEED GERMINATION

Distribution of the plant species is influenced by seed germination (Went, 1957). Seed germination of a plant species is influenced profoundly by environmental factors (Newman, 1964). Frequently it appears that there is a close relationship between climatic condition for germination and ecological conditions occurring in a habit of the plant and the seed (Mayer and Mayber, 1963).

The effect of two climatic factors i.e. temperature and light and one edaphic factor i.e. pH on germination is presented in this chapter.

T.T.C. reaction gave 99 percent viability for Terminalia arjuna and Albizzia lebbeck and 95 percent viability for the seeds of Dalbergia sissoo.

LIGHT AND DARK EFFECT ON GERMINATION

The light effect on seed germination is significant in all the three species (Tables 5.1).

Table 5.1: Germination percentage in dark and in different light conditions.

Species	Percentage germination			
	Dark	White light	Red light	Blue light
<i>Albizzia lebbeck</i>	54±2.5	56 ± 5.6	74 ± 7.5	79 ± 4.0
<i>Dalbergia sissoo</i>	74 ± 4.4	64 ± 8.9	93 ± 2.1	94 ± 3.1
<i>Terminalia Arjuna</i>	79 ± 5.5	70 ± 7.0	0	0

0 indicates no germination

The results in Table 5.1 show that maximum percentage of germination for A. lebbek and D. sissoo is 79 ± 4.0 and 74 ± 3.1 respectively in blue light but in T. arjuna no germination took place in red and blue lights.

On the basis of F values presented in tables 5.2, 5.3 and 5.4 it is evident that in case of A. lebbek and T. arjuna for components the values are lower indicating more significant in comparison to D. sissoo in which F value (17.1) is higher.

Table 5.2: Germination in different light and dark conditions for A. lebbek

ANALYSIS OF VARIANCE

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	2	38.07	19.0	1.2*
Treatment	3	1478.20	492.7	
Error	6	232.89	38.8	
Total	11			

* Significant at 1% level

Table 5.3: Germination in different light and dark conditions in *D. sissoo***ANALYSIS OF VARIANCE**

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	2	350.04	175.50	17.1*
Treatment	3	1896.40	632.46	
Error	6	219.77	36.62	
Total	11			

* Significant at 5% level

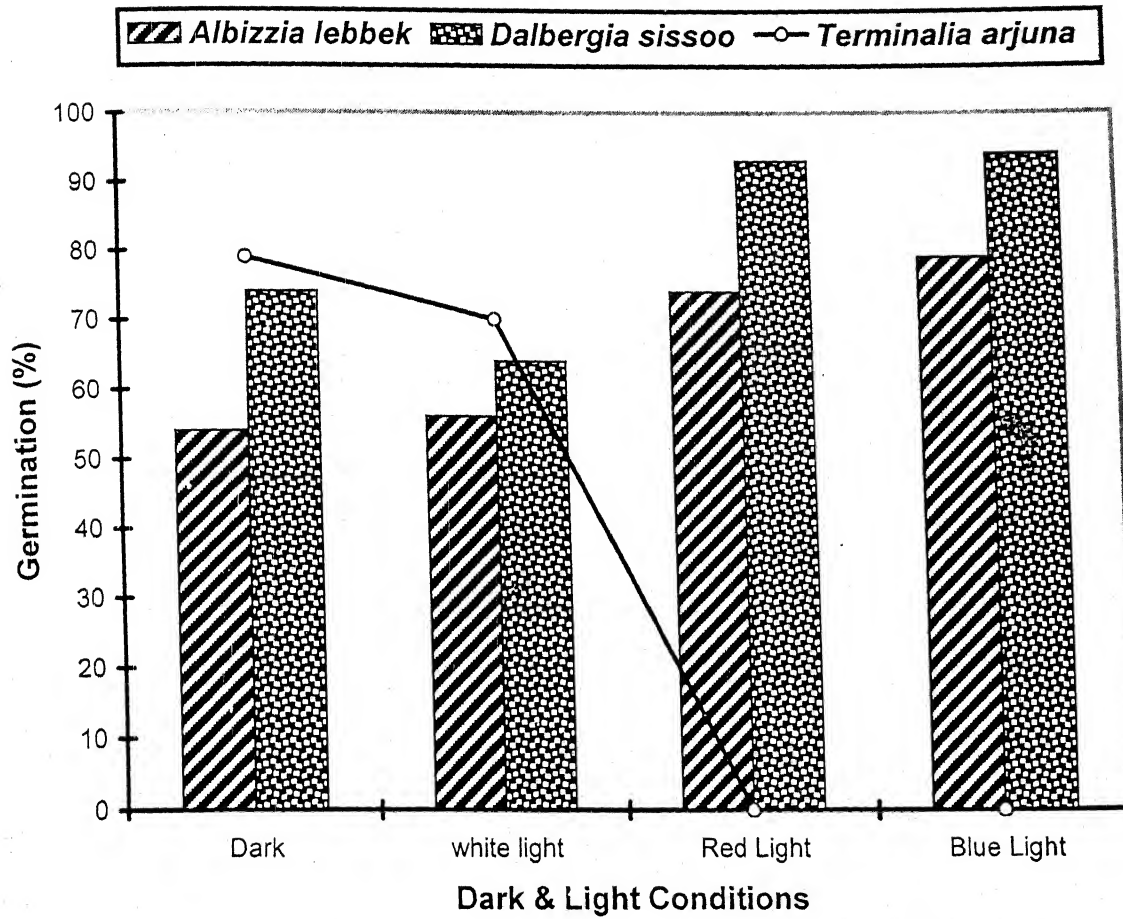
Table 5.4: Germination in different light and dark Conditions in *T. arjuna***ANALYSIS OF VARIANCE**

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	2	58.4	29.0	1.7*
Treatment	1	150.0	150.0	
Error	2	175.0	87.5	
Total	5			

* Significant at 1% level.

It is evident from Fig. 5.1 that the maximum germination percentage is recorded in the dark for T. arjuna seeds.

Fig. 5.1 - Germination percentage in different light conditions and in complete darkness.



TEMPERATURE EFFECT ON GERMINATION

Table 5.5 and Fig. 5.2 indicates that the germination percentage of seeds for A. lebbek increases with rising temperature nearly upto 40°C.

At the lower temperature of 15°C, no appreciable germination was noted in both A. lebbek and T. arjuna but in D. sissoo 89 per cent germination was recorded. In this particular species the germination percentage in D. sissoo and T. arjuna was recorded at room temperature (28-38°C), where as in A. lebbek at room temperature (10-20°C)

Table 5.5: Germination percentage at different temperatures.

Species	Temperature (°C)				
	15	20	30	40	Room Temp.
<i>Albizia lebbek</i>	2.0 ± 1.0	48.0 ± 8.6	52.1 ± 15.0	75.1 ± 7.6	40.1 ± 9.6*
<i>Lalbergia sissoo</i>	59.0 ± 2.0	-	-	59.0 ± 15.6	90.0 ± 8.8**
<i>Terminalia arjuna</i>	8.5 ± 1.1	-	69.0 ± 6.0	64.0 ± 7.0	88.0 ± 4.6**

* Room Temperature 10-20°C

** Room Temperature 28-38°C

- Not Recorded.

germination percentage was 40.1 ± 9.6. The overall temperature suitable for germination in all the three species is 30 to 40°C.

Fig. 5.2 - Germination percentage at different temperatures.

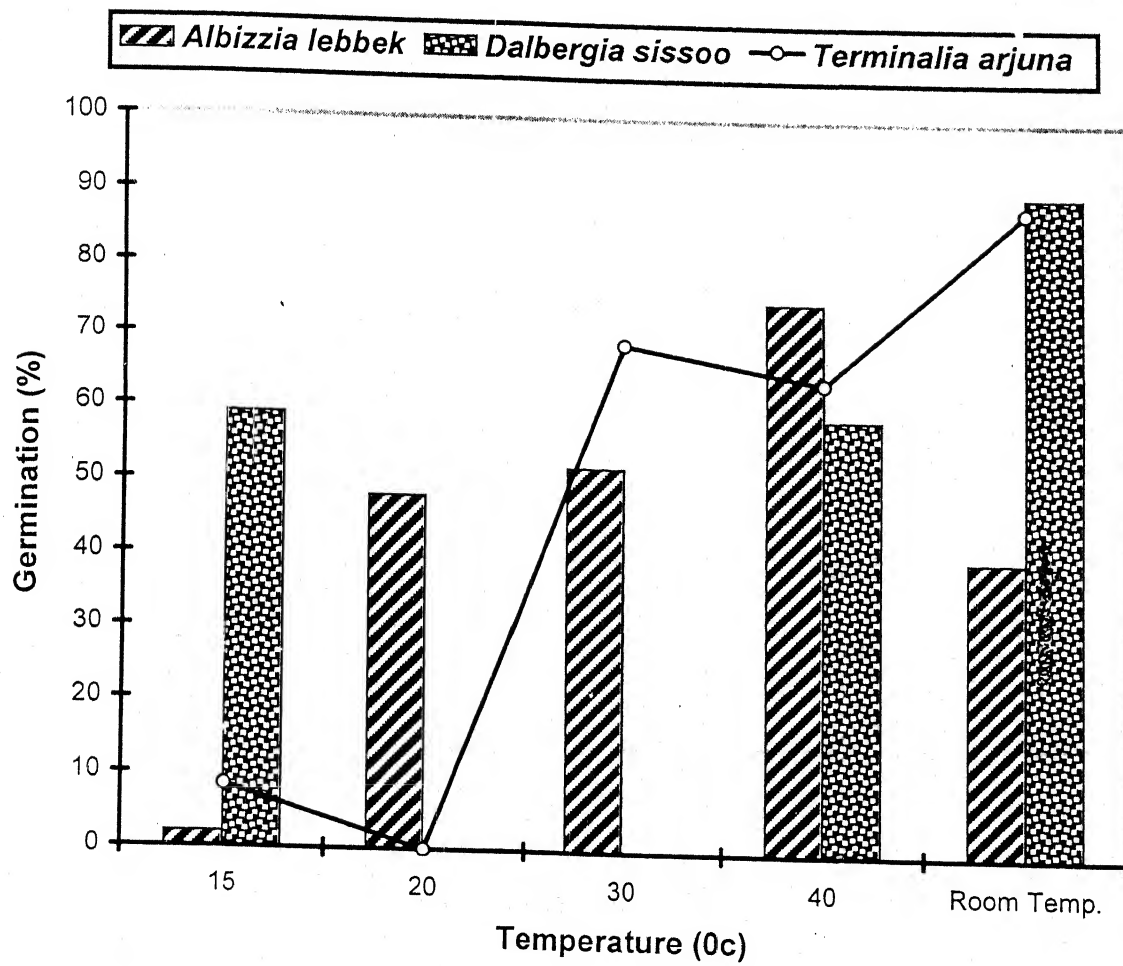


Table 5.6: seed germination at different Temperature in *A. lebbek***ANALYSIS OF VARIANCE**

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	4	504.04	126.17	39.4*
Treatment	4	14400.7	3600.17	
Error	16	1460.9	91.3	
Total	24			

* Significant at 5% level

Table 5.7: Seed germination at different temperature in *D. sissco***ANALYSIS OF VARIANCE**

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	4	94.0	23.5	9.7*
Treatment	2	3203.4	1601.7	
Error	8	1318.0	164.7	
Total	14			

* Significant at 1% level

Table 5.8: Seed germination at different temperature in *T. arjuna*ANALYSIS OF VARIANCE

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	4	113.1	28.2	62*
Treatment	3	18720.6	6240.2	
Error	12	1201.1	108.0	
Total	19			

* Significant at 5% level

EFFECT OF PH ON GERMINATION

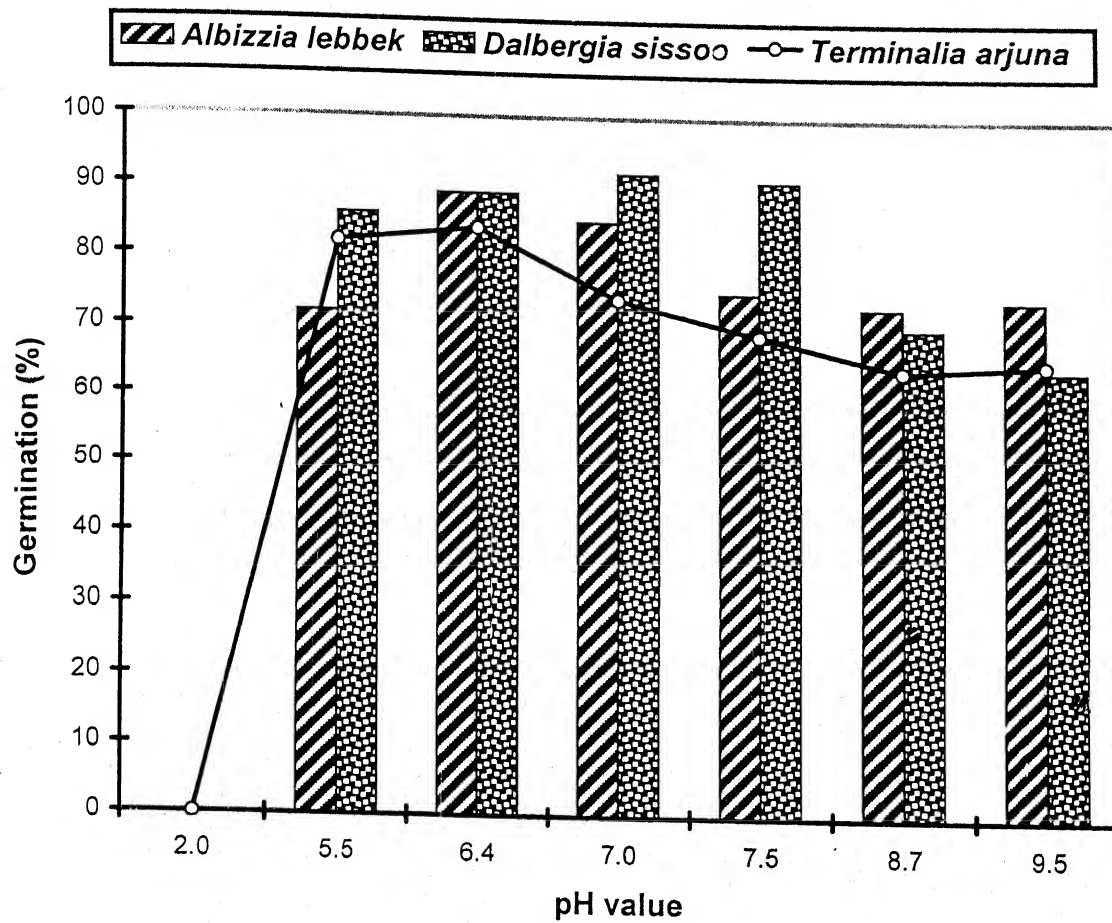
In general, as shown in Fig. 5.3, the seed germination of all the three species is favoured by slightly acidic pH. Maximum germination percentage in *A. lebbek* and *T. arjuna* is recorded 89 and 84 per cent at pH 6.4 respectively. In *D. sissoo* maximum germination percentage is recorded 92 percent at 7.0 pH (Table 5.9).

Table 5.9: Germination percentage at different pH values

Species	pH values						
	2.0	5.5	6.4	7.0	7.5	8.7	9.5
<i>Albizzia lebbek</i>	x	72 ± 3.5	89 ± 5.4	85 ± 3.1	75 ± 3.1	73 ± 1.3	74 ± 2.5
<i>Dalbergia sissoo</i>	x	86 ± 3.1	89 ± 3.0	92 ± 3.0	91 ± 1.3	70 ± 5.1	64 ± 2.1
<i>Terminalia arjuna</i>	x	82 ± 8.1	84 ± 11.0	74 ± 4.1	69 ± 8.0	64 ± 4.1	65 ± 3.5

X

No germination took place



Any change of pH on either side brings a significant reduction of germination percentage of all the three species. It has been observed that strongly acidic medium (pH 2) inhibits germination completely. Overall range of pH for germination is 6.4 - 7.0.

Table 5.10: Germination of *A. lebbek* seed at different pH of the medium

ANALYSIS OF VARIANCE

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	4	22.5	5.6	18.7*
Treatment	5	1283.5	256.7	
Error	20	277.5	13.7	
Total	29			

* Significant at 1% level

Table 5.11 : Germination of *D. sissoo* seed at different pH of the medium

ANALYSIS OF VARIANCE

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	2	127	63.5	4.9*
Treatment	5	215	43.0	
Error	10	2140	214.0	
Total	17			

* Significant at 1% level

Table 5.12: Germination of *T. arjuna* seed at different pH of the mediumANALYSIS OF VARIANCE

Source of variation	Degree of Freedom	Sum of squares	Mean sum of squares	F value
Replication	2	252.0	126.0	8.3*
Treatment	6	1592.5	265.4	
Error	12	380.0	31.6	
Total	20			

* Significant at 1% level

CHAPTER - VI

**GROWTH ANALYSIS OF
SEEDLINGS**

GROWTH ANALYSIS OF SEEDLINGS

NET ASSIMILATION RATE (NAR)

The values of NAR are shown in Fig. 6.1. As clear from the figure in each case the N A R values rise to a peak early in the growing season at the age of 3 or 4 months. Further it declines steadily. Again it gives a peak in all the seedlings when they were of the age of 8 or 9 months. Negative values of N A R were also observed. Table 6.1, shows the values of NAR for all the three species during the year 1999-2000. The maximum value of NAR is recorded in Terminalia arjuna at one month age of the seedling. It is 0.048 g/cm²/month at the seedling age of one month. The maximum value of NAR recorded for Albizia lebbek and Dalbergia sissoo was 0.026 and 0.037 g/cm²/month respectively at the seedling age of one month. These results suggest that NAR varies from species to species.

RELATIVE GROWTH RATE (RGR)

Table 6.2 and Fig. 6.2 shows the value of RGR for all the three species. The maximum value of RGR throughout the experimental period for T. arjuna and A. lebbek, at the age of 6 months, were 0.532 and 0.533g/g/month respectively. But for D. sissoo this value was g/g/month at the age of 5 months, Fig. 6.2 shows the negative value of RGR in D. sissoo and T. arjuna when the seedlings were of 10, 11 and 12 months old, but A. lebbek showed negative values at the age of 11 and 12 months.

MEAN LEAF WEIGHT RATIO (M L W R)

The ratio of the leaf to plant weight (MLWR) was calculated and the results are presented in Table 6.3. The variation with age in MLWR is shown for all the three species under study (Fig. 6.3). In all the species an annual peak of MLWR was attained. After this it declined gradually in all the species. Extensive overall difference was observed between species. Throughout the experiment the average value recorded for T. arjuna (42.80 cm²/g/month) and D. sissoo (54.52 cm²/g/month) were lower than those recorded for A. lebbek i.e. 60.92 cm²/g/month).

The mean values of NAR were calculated for the period between successive harvests in all the three species. According to William (1946) the formula used to calculate NAR is accurate only if there is linear relationship between leaf area and plant weight. Such a relationship exists when MLWR is constant with time. It is clear from Fig. 6.3, that in T. arjuna the change in MLWR with time was not great, and thus the NAR values calculated should not include a large error. But in A. lebbek and D. sissoo, where the changes in MLWR with time were considerable, error in the calculated NAR values must have been correspondingly much larger.

Table 6.1: Net Assimilation Rate (mg/cm²/month) at different ages of
Seedlings of *A. lebbek*, *D. sissoo* and *T. arjuna*

Age (months)	<i>A. lebbek</i>	<i>D. sissoo</i>	<i>T. arjuna</i>
1	0.026	0.037	0.048
2	0.013	0.001	0.044
3	0.007	0.003	0.024
4	0.0004	0.007	0.0001
5	0.007	0.011	0.0002
6	0.013	0.006	0.011
7	0.001	0.0005	0.0008
8	0.0004	0.004	0.007
9	0.003	0.002	0.001
10	0.0001	-0.004	-0.002
11	-0.005	-0.001	-0.007
12	-0.003	-0.006	-0.004

Table 6.2: Relative Growth Rate (g/g/month) of seedlings of *A. lebbek*,
D. sissoo and *T. arjuna* at different stages of their growth

Age (months)	<i>A. lebbek</i>	<i>D. sissoo</i>	<i>T. arjuna</i>
1	-2.040	-1.514	-1.238
2	0.879	0.062	1.489
3	0.411	0.120	0.929
4	0.022	0.487	0.003
5	0.337	0.536	0.019
6	0.533	0.291	0.532
7	0.049	0.027	0.040
8	0.038	0.248	0.318
9	0.203	0.148	0.082
10	0.006	-0.299	-0.119
11	-0.174	-0.115	-0.442
12	-0.644	-0.394	-1.068

Table 6.3: Mean Leaf Weight Ratio (cm^2/g dry wt./month) of different seedlings of *A. lebbek*, *D. sissoo* and *T.arjuna* at different age

Age (months)	<i>A. lebbek</i>	<i>D. sissoo</i>	<i>T. arjuna</i>
1	-79.500	-23.08	-25.13
2	77.60	45.61	34.34
3	56.73	73.44	37.98
4	53.32	68.18	50.09
5	47.06	48.23	56.41
6	41.41	31.00	46.22
7	53.43	51.26	43.14
8	69.94	59.40	43.23
9	69.58	67.97	47.24
10	77.88	71.02	51.72
11	98.07	74.54	56.85
12	86.10	63.57	46.54

Fig. 6.1 - Net assimilation ratio of different seedlings of *Albizzia lebbek*,
Dalbergia sissoo and *Terminalia arjuna* at different age.

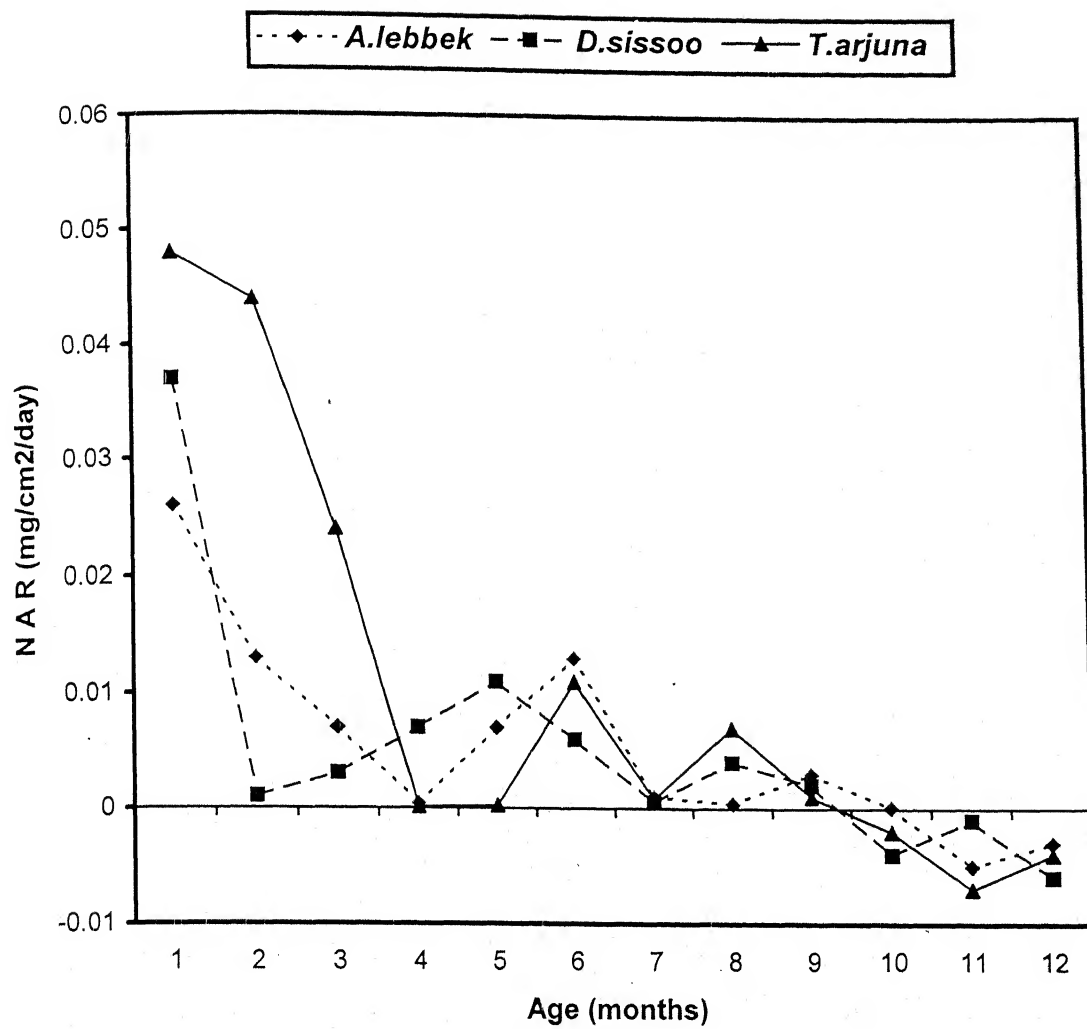


Fig. 6.2 - Relative growth rate of seedlings of *Albizzia lebbek*, *Dalbergia sissoo* and *Terminalia arjuna* at different stages of their growth.

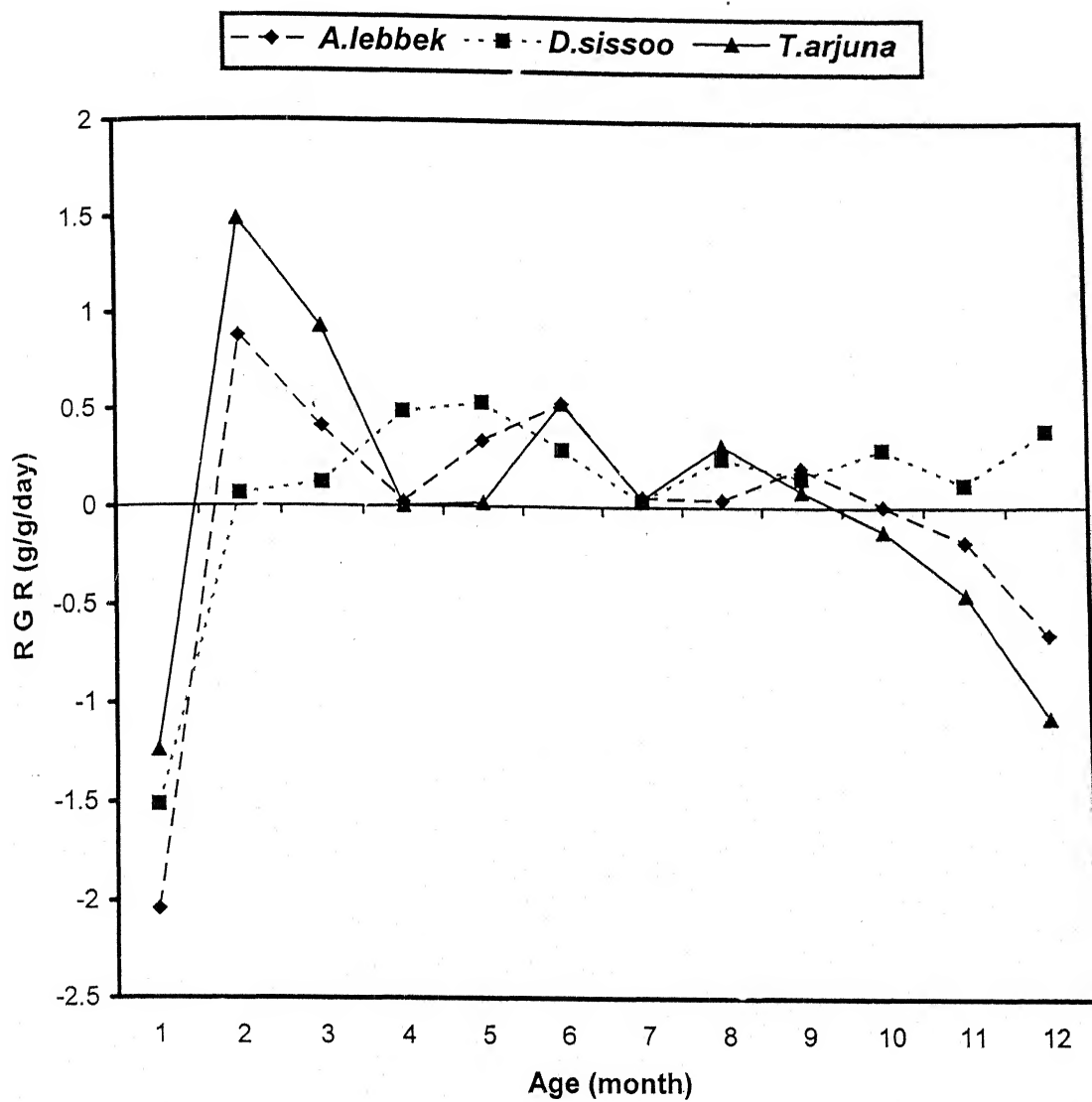
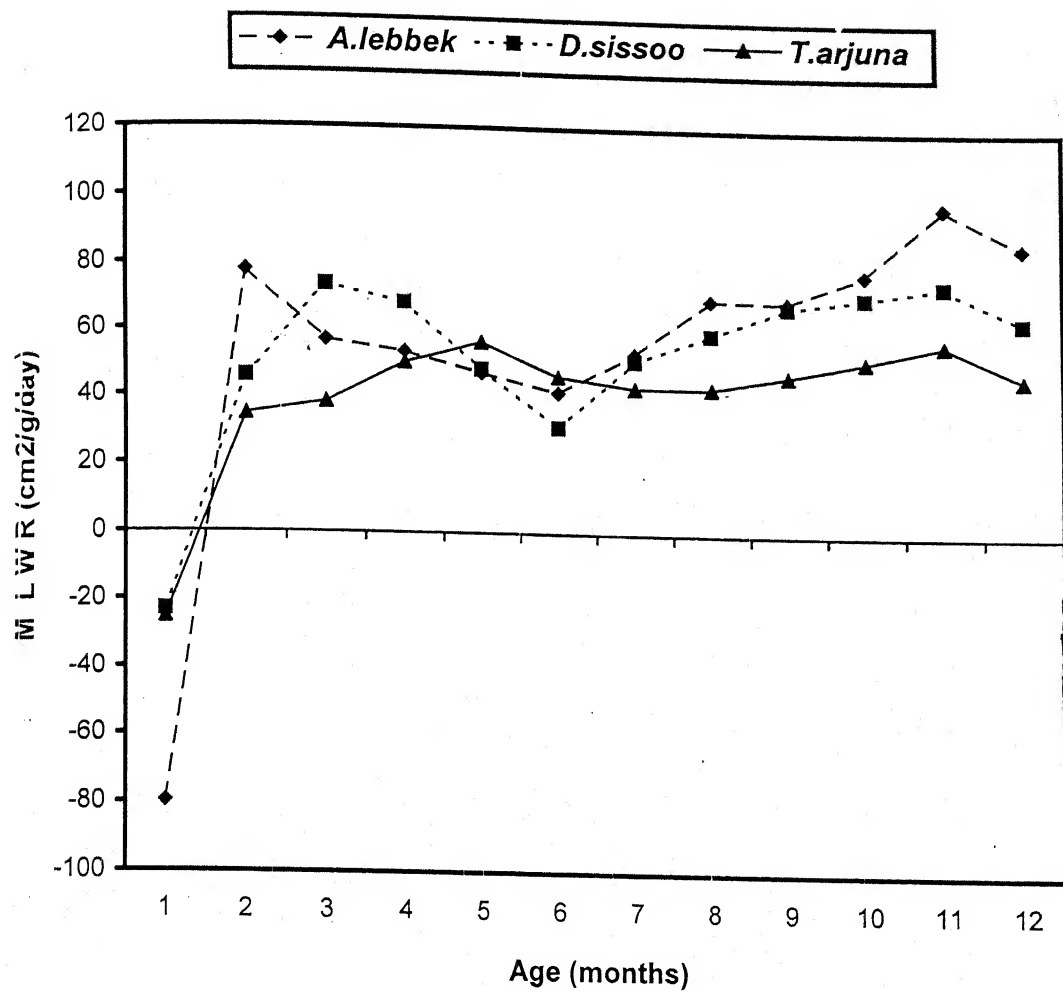


Fig. 6.3 - Mean leaf weight ratio of seedlings of *Albizzia lebbek*, *Dalbergia sissoo* and *Terminalia arjuna* at different age.



CHAPTER - VII

BIOMASS AND PRODUCTIVITY

BIOMASS AND PRODUCTIVITY

Standing crop biomass of fractional plant parts. viz. leaves, stem and root, productivity and chlorophyll of Albizzia lebbek, Dalbergia sissoo and Terminalia arjuna seedlings upto one year age are discussed in this chapter. The return of organic matter to the soil with the litterfall and the interrelationship among different growth parameters have also been described.

BIOMASS STUDY

Data on the dry matter content of different plant parts and the standing crop biomass of A. lebbek, D. sissoo and T. arjuna are recorded in Tables 7.1, 7.2 and 7.3 respectively. The biomass per plant increases with the age in all the three species. It is noted from the data presented in the tables that D. sissoo and T. arjuna seedlings contributed the maximum biomass 1.832 and 8.792 g per plant respectively at the age of nine months. But in case of A. lebbek it is recorded to be 1.792 g/plant at the age of 10 months. The minimum biomass values at the age of one month are 0.130, 0.220 and 0.290 g per plant in A. lebbek, D. sissoo and T. arjuna respectively.

The distribution of biomass of root, stem and leaves at different months is shown in Figs. 7.1, 7.2 and 7.3. The dry weight of leaves and root per plant in A. lebbek seedling attains a peak at ten months age for which the corresponding values are 0.454 and 0.968 g (Table 7.1), but for stem the same was found 0.476 g/plant at 8 months age. Similarly in case of D. sissoo

Table 7.1: Total standing crop biomass (g/plant) of different components of *A. lebbek* seedling

Age (Months)	Leaf	Stem	Root	Total
1.	0.060 ± 0.018	0.036 ± 0.008	0.034 ± 0.010	0.130 ± 0.010
2	0.180 ± 0.077	0.092 ± 0.034	0.090 ± 0.030	0.362 ± 0.082
3	0.302 ± 0.186	0.150 ± 0.087	0.094 ± 0.094	0.546 ± 0.303
4	0.144 ± 0.055	0.160 ± 0.049	0.254 ± 0.089	0.558 ± 0.165
5	0.303 ± 0.187	0.280 ± 0.140	0.199 ± 0.071	0.782 ± 0.214
6	0.350 ± 0.052	0.412 ± 0.205	0.670 ± 0.235	1.432 ± 0.283
7	0.272 ± 0.037	0.437 ± 0.195	0.690 ± 0.225	1.399 ± 0.306
8	0.126 ± 0.097	0.476 ± 0.058	0.852 ± 0.203	1.454 ± 0.320
9	0.450 ± 0.243	0.402 ± 0.197	0.930 ± 0.160	1.782 ± 0.892
10	0.454 ± 0.246	0.370 ± 0.176	0.968 ± 0.653	1.792 ± 0.895
11	0.176 ± 0.085	0.352 ± 0.092	0.522 ± 0.142	1.050 ± 0.342
12	0.132 ± 0.054	0.242 ± 0.149	0.416 ± 0.329	0.790 ± 0.214

Table 7.2: Total standing crop biomass (g/plant) of different components of *D. sissoo* seedling

Age (Months)	Leaf	Stem	Root	Total
1	0.091 ± 0.031	0.064 ± 0.008	0.055 ± 0.010	0.220±0.052
2	0.100 ± 0.021	0.072 ± 0.011	0.062 ± 0.011	0.234±0.024
3	0.150 ± 0.065	0.082 ± 0.021	0.090 ± 0.030	0.322±0.111
4	0.302 ± 0.186	0.152 ± 0.051	0.070 ± 0.023	0.524±0.321
5	0.199 ± 0.071	0.298 ± 0.054	0.399 ± 0.143	0.896±0.461
6	0.230 ± 0.092	0.327 ± 0.096	0.643 ± 0.105	1.200±0.457
7	0.082 ± 0.029	0.392 ± 0.152	0.758 ± 0.204	1.232±0.468
8	0.398 ± 0.287	0.420 ± 0.207	0.762 ± 0.200	1.580±0.475
9	0.502 ± 0.181	0.430 ± 0.215	0.900 ± 0.257	1.832±0.076
10	0.265 ± 0.042	0.417 ± 0.015	0.676 ± 0.074	1.358±0.531
11	0.238 ± 0.095	0.328 ± 0.097	0.644 ± 0.106	1.210±0.206
12	0.140 ± 0.043	0.298 ± 0.146	0.378 ± 0.135	0.816±0.303

Table 7.3: Total standing crop biomass (g/plant) of different components of *T. arjuna* seedling

Age (Months)	Leaf	Stem	Root	Total
1.	0.170 ± 0.021	0.072 ± 0.013	0.048 ± 0.017	0.290 ± 0.051
2	0.742 ± 0.228	0.342 ± 0.109	0.202 ± 0.022	1.286 ± 0.319
3	1.408 ± 0.399	1.046 ± 0.247	0.802 ± 0.182	3.256 ± 0.789
4	0.890 ± 0.361	1.116 ± 0.575	1.260 ± 0.638	3.266 ± 1.490
5	0.878 ± 0.359	1.126 ± 0.308	1.322 ± 0.276	3.326 ± 1.456
6	1.498 ± 0.456	1.690 ± 0.367	2.476 ± 0.371	5.664 ± 0.408
7	1.432 ± 0.398	1.190 ± 0.456	3.272 ± 0.856	5.894 ± 0.030
8	1.534 ± 0.481	2.740 ± 0.425	3.826 ± 1.332	8.100 ± 0.964
9	1.630 ± 0.422	3.210 ± 0.679	3.952 ± 0.920	8.792 ± 0.746
10	0.902 ± 0.251	2.765 ± 0.756	4.140 ± 0.795	7.807 ± 0.354
11	0.818 ± 0.185	1.148 ± 0.461	3.054 ± 0.897	5.020 ± 0.257
12	0.692 ± 0.074	1.530 ± 0.478	2.470 ± 0.367	4.692 ± 0.491

Fig. 7.1 - Variation in biomass of different plant parts with increasing age of *Albizzia lebbek* seedling.

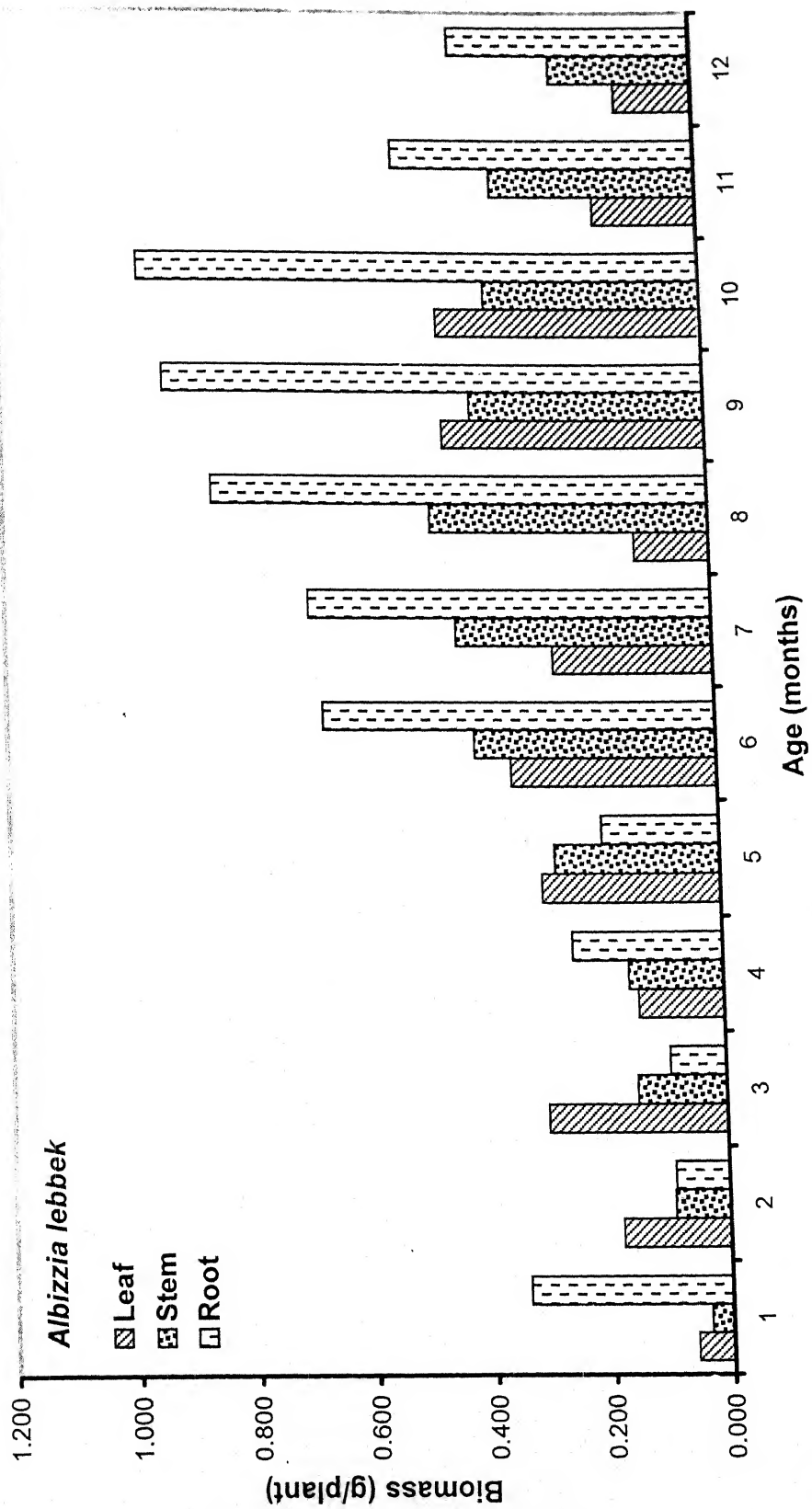


Fig. 7.2 - Variation in biomass of different plant parts with increasing age of *Dalbergia sissoo* seedling.

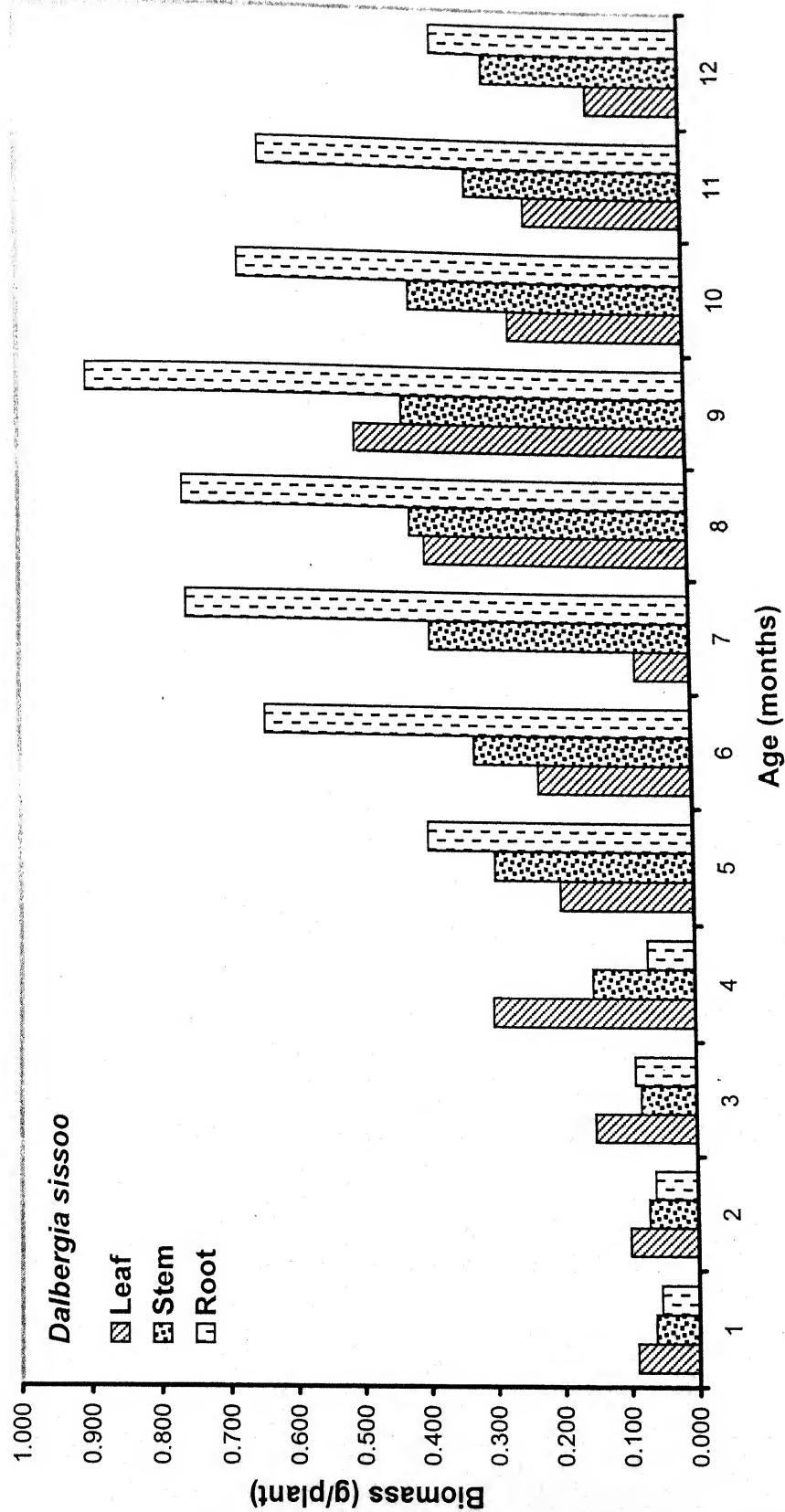
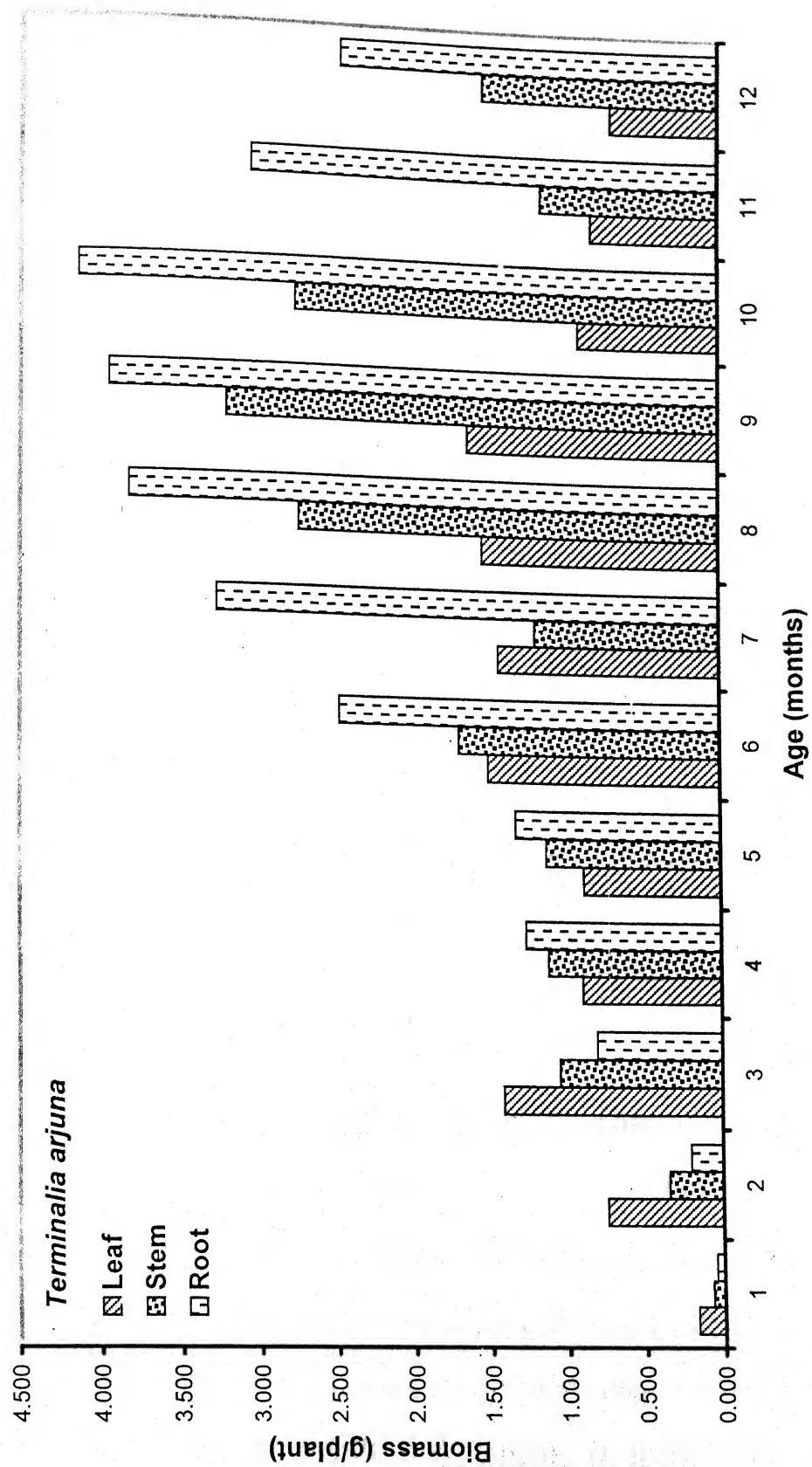


Fig. 7.3 - Variation in biomass of different plant parts with increasing age of *Terminalia arjuna* seedling.



the maximum biomass for leaves, stem and root was recorded 0.502, 0.430 and 0.900 g/plant respectively at the age of nine months (Table 7.2). In case of T. arjuna the maximum dry weight for leaves and stem was noted to be 1.630 and 3.210 g/plant respectively at 9 months age but for root it is noted to be 1.140 g/plant at the age of 10 months (Table 7.3). The dry content for leaves, stem and root of the above mentioned plants remains minimum i.e. 0.060, 0.036, 0.034; 0.091, 0.064, 0.055 and 0.170, 0.072 and 0.048 g per plant respectively in one month seedlings (Table 7.1, 7.2 and 7.3).

The dry weight of leaves increases with age of the plant and attains a peak value followed by reduction. In all the species the overall trend of dry matter accumulation in component plant parts of different age seedling is very similar to each other. It is evident from Fig. 7.4 that in all the species root weight increase rapidly with age.

The percentage of leaf biomass to the total biomass is maximum at the early age of all the three species. It ranges between 55.31 to 58.62 per cent (Tables 7.4, 7.5, 7.6 and Fig. 7.5, 7.6 and 7.7). It decreases with age and in one year seedlings it remains only 16.71, 17.16 and 14.75 per cent in A. lebbek, D. sissoo, and T. arjuna respectively for leaves. The percentage root biomass shows positive correlation with age. It increases with increasing age. In one month seedling it contributes a small percentage of biomass that is only 26.15, 25.00, and 16.55% in A. lebbek, D. sissoo and T. arjuna respectively. The root biomass of one year old seedling of A. lebbek, D. sissoo and T. arjuna contributes 52.66, 46.32 and 52.64 per cent to the total plant

Table 7.4: Percentage contribution of different component plant parts to the total plant biomass of *A. lebbek* seedling

Age (Months)	Leaf	Stem	Root
1	46.15	27.69	26.15
2	49.72	25.41	24.86
3	55.31	27.47	17.22
4	25.80	28.67	45.52
5	38.75	35.80	25.45
6	18.77	30.93	50.30
7	19.44	31.24	49.32
8	8.66	32.74	58.59
9	25.25	22.56	52.19
10	25.33	20.65	54.02
11	16.76	33.52	49.71
12	16.71	30.63	52.66

Table 7.5: Percentage contribution of different component plant parts to the total plant biomass of *D.sissoo* seedling

Age (Months)	Leaf	Stem	Root
1	41.36	29.00	25.00
2	42.73	30.77	26.49
3	46.58	25.46	27.95
4	57.63	29.01	13.36
5	22.21	33.26	44.53
6	19.17	27.25	53.58
7	6.65	31.82	61.52
8	25.19	26.58	48.23
9	27.40	23.47	49.13
10	19.51	30.71	49.78
11	19.67	27.11	53.22
12	18.15	36.52	46.32

Table 7.6: Percentage contribution of different component plant parts to the total plant biomass of *T. arjuna* seedling

Age (Months)	Leaf	Stem	Root
1	58.62	24.83	16.55
2	57.70	26.59	15.71
3	43.24	32.12	24.63
4	27.25	34.17	38.58
5	26.40	33.85	39.75
6	26.45	29.84	43.71
7	24.29	20.19	55.51
8	18.94	33.83	47.23
9	18.54	36.51	44.95
10	11.55	35.42	53.03
11	16.29	22.87	60.84
12	14.75	32.61	52.64

Fig. 7.4 - Aboveground and underground plant biomass and rate of production at different age of seedlings of *Albizzia lebbek*, *Dalbergia sissoo* and *Terminalia arjuna*.

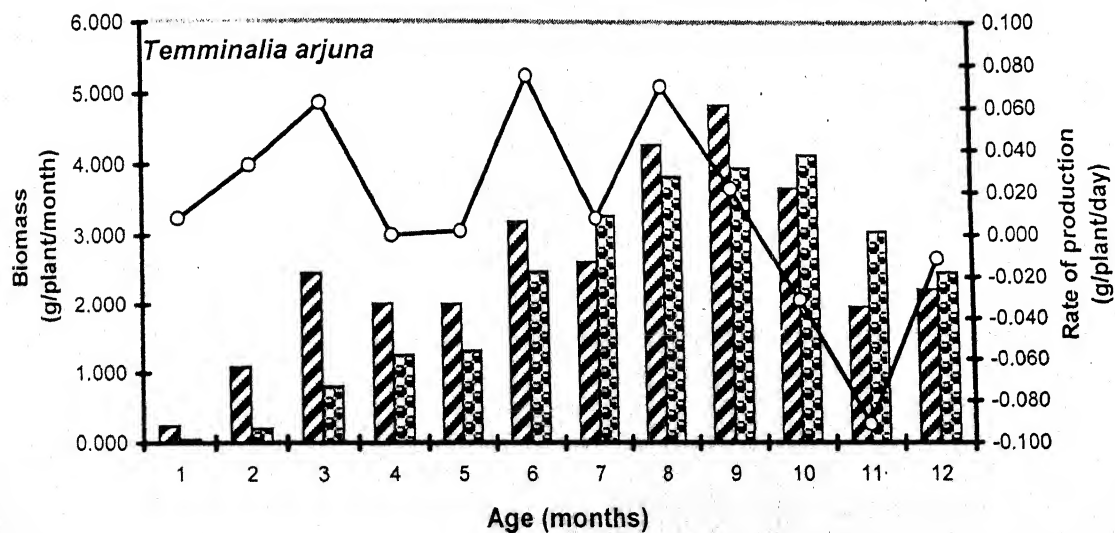
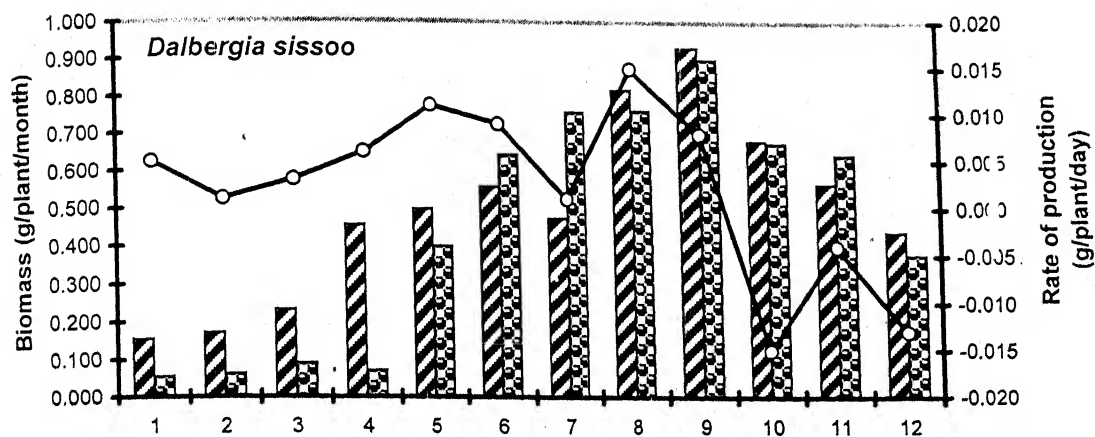
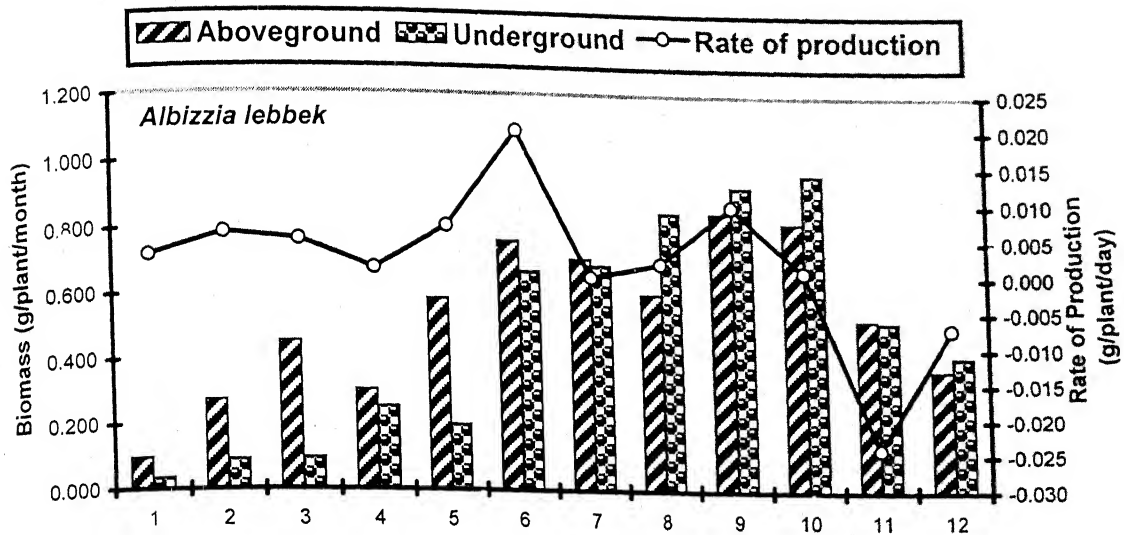


Fig. 7.5 - Percentage biomass in different components of different age of seedlings of *Albizzia lebbek*.

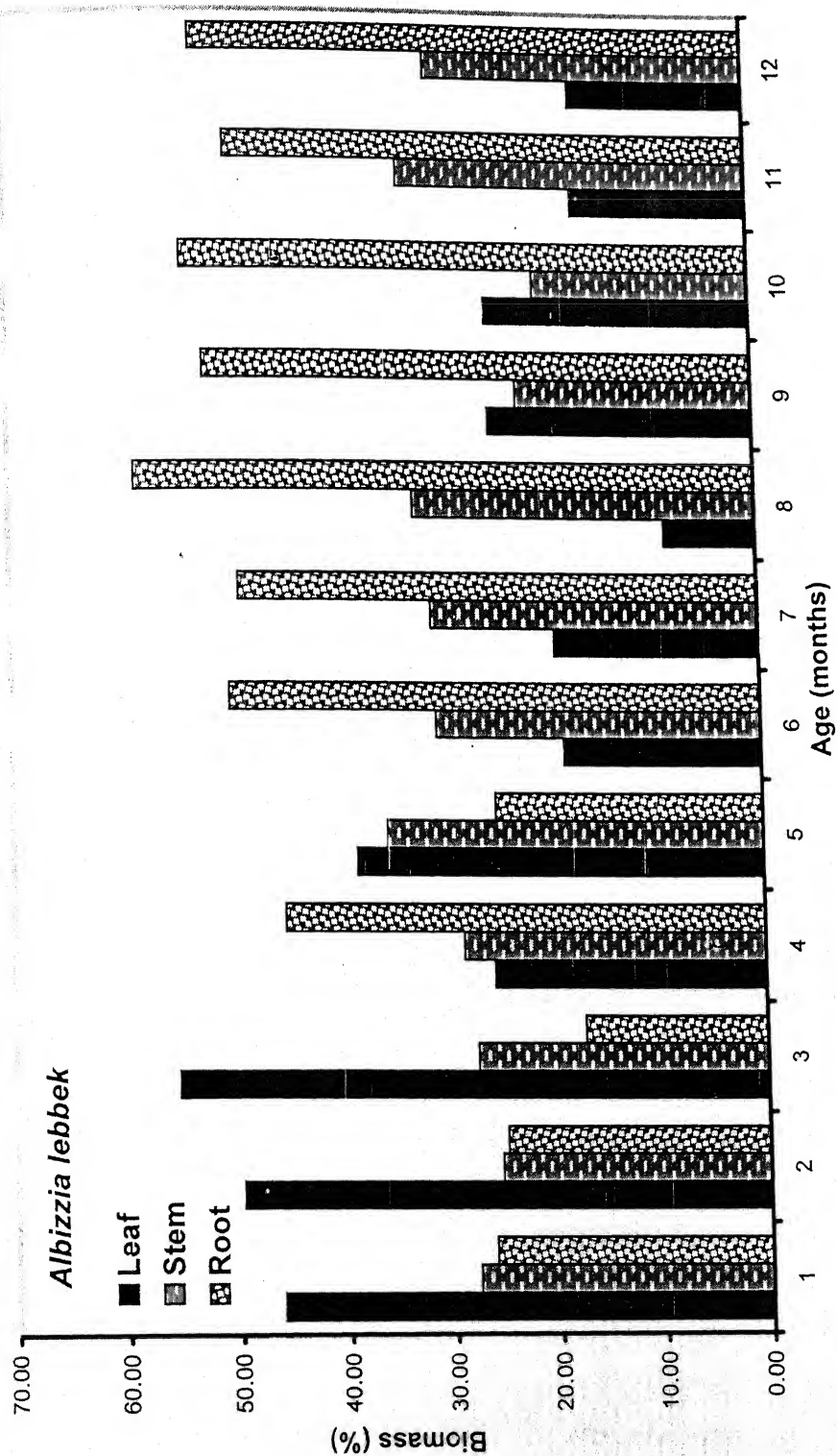


Fig. 7.6 -Percentage biomass in different components of different age of seedlings of *Dalbergia sissoo*.

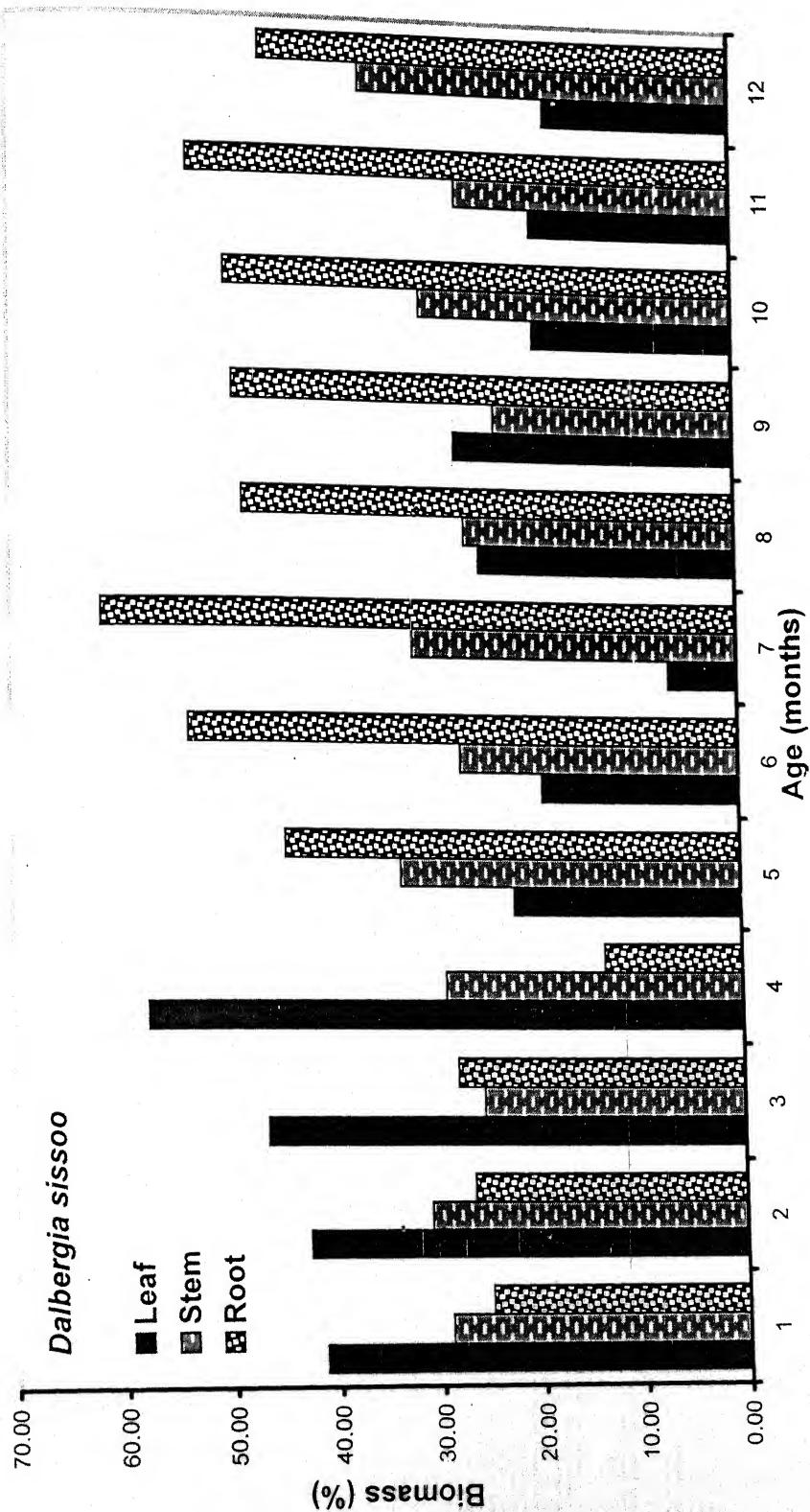
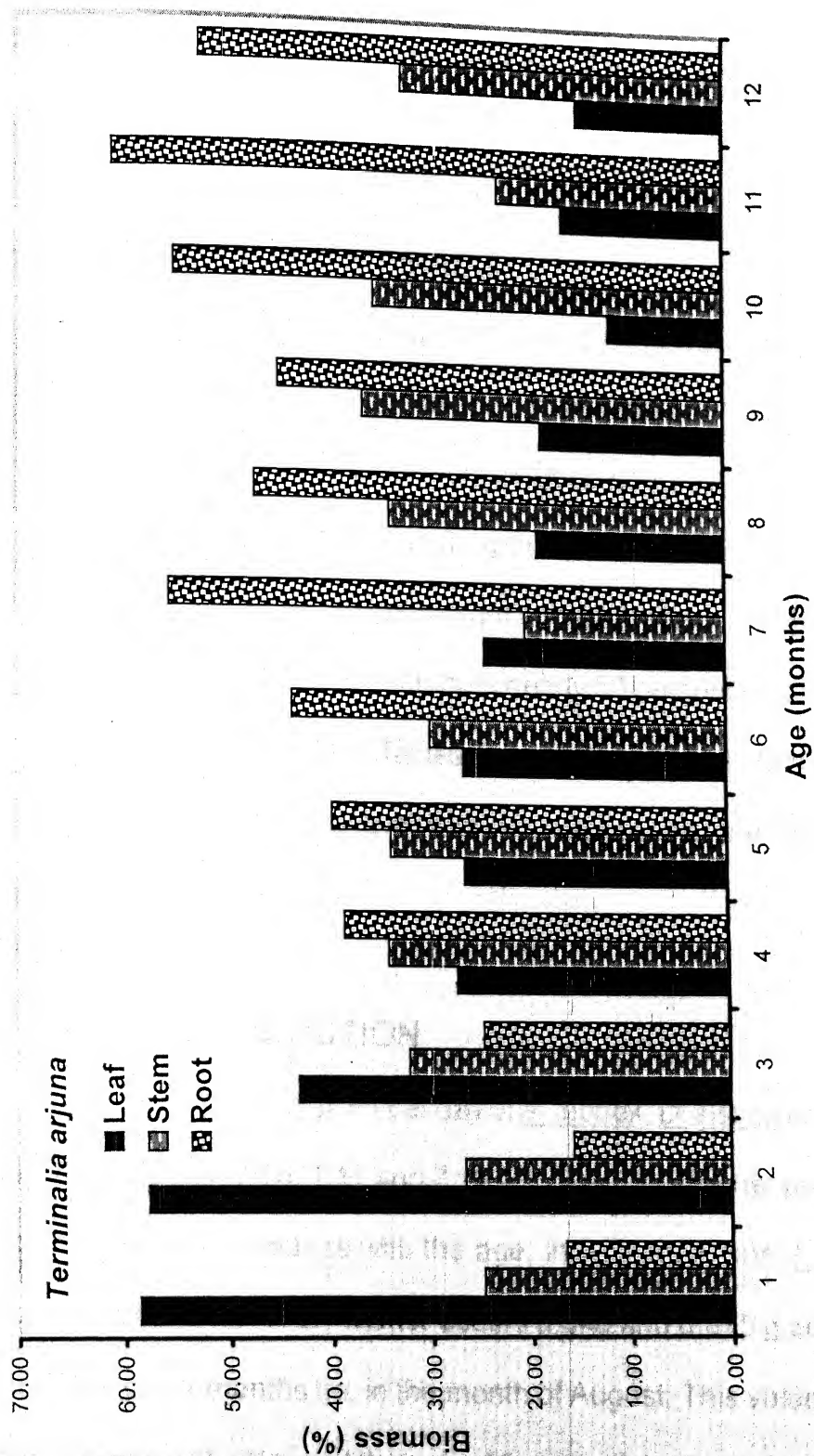


Fig. 7.7 - Percentage biomass in different components of different age of seedlings of *Terminalia arjuna*.



biomass respectively. The percentage contribution of stem biomass remains more or less the same throughout the year Fig. 7.5, 7.6 and 7.7 (Table 7.4, 7.5 and 7.6).

RATIOS OF THE PLANT BIOMASS

The ratios of the underground and above ground plant biomass in A. lebbek, D. sissoo and T. arjuna are shown in Tables 7.7, 7.8 and 7.9 and Fig. 7.8. It clearly indicates that in younger trees contribution of the above ground parts is higher than that of underground but with increasing age the reverse holds true. If we see the leaf weight and plant weight ratios it is found that at the younger stage leaves contribute nearly 50 percent of the total plant weight in all the three species (Tables 7.7, 7.8, 7.9). But it decreases with increasing age while in the case of root it increases with the age in all the three species.

NET PRIMARY PRODUCTION

Productivity per plant per day of A. lebbek, D. sissoo and T. arjuna is presented in Tables 7.10, 7.11 and 7.12 and Fig. 7.9. The net production in all the three species increases with the age. In A. lebbek, and T. arjuna the maximum accumulation of dry matter occurs 0.046 and 0.075 g per plant per day at the age of six months i.e. in the month of August. This value is 0.012 g per plant per day in D. sissoo at the age of five month i.e. in the month of July. After receiving the maximum value it decreases in all the three species.

Table 7.7: Ratios of the total plant weight and component plant parts in

A. lebbek seedling

Age (Months)	Leaf wt./ plant wt.	Stem wt./ plant wt.	Root wt./ plant wt.	Root/shoot
1	0.461	0.276	0.261	0.354
2	0.497	0.254	0.248	0.330
3	0.553	0.274	0.172	0.207
4	0.258	0.286	0.455	0.835
5	0.387	0.358	0.254	0.341
6	0.187	0.309	0.503	1.012
7	0.194	0.312	0.493	0.973
8	0.086	0.327	0.585	1.415
9	0.252	0.225	0.521	1.091
10	0.253	0.206	0.540	1.174
11	0.167	0.335	0.497	0.988
12	0.167	0.306	0.526	1.112

Table 7.8: Ratios of the total plant weight and component plant parts in
D. sissoo seedling

Age (Months)	Leaf wt./ plant wt.	Stem wt./ plant wt.	Root wt./ plant wt.	Root/shoot
1	0.263	0.545	0.190	0.235
2	0.427	0.307	0.264	0.360
3	0.465	0.254	0.279	0.387
4	0.576	0.290	0.133	0.154
5	0.222	0.332	0.445	0.802
6	0.191	0.272	0.535	1.154
7	0.066	0.318	0.615	1.599
8	0.251	0.165	0.482	0.931
9	0.274	0.234	0.491	0.965
10	0.195	0.307	0.497	0.991
11	0.196	0.271	0.532	1.137
12	0.171	0.365	0.463	0.863

**Table 7.9: Ratios of the total plant weight and component plant parts in
T. arjuna seedling**

Age (Months)	Leaf wt./ plant wt.	Stem wt./ plant wt.	Root wt./ plant wt.	Root/shoot
1	0.586	0.248	0.165	0.198
2	0.576	0.265	0.157	0.186
3	0.432	0.321	0.246	0.326
4	0.272	0.341	0.385	0.628
5	0.263	0.338	0.397	0.659
6	0.264	0.298	0.437	0.776
7	0.242	0.201	0.555	1.247
8	0.189	0.338	0.472	0.895
9	0.185	0.365	0.449	0.816
10	0.115	0.354	0.530	1.128
11	0.162	0.228	0.608	1.553
12	0.147	0.326	0.526	1.111

Table 7.10: Rate of production (g/plant/day) of different component plant parts of *A. lebbek* seedling

Age (Months)	Leaf	Stem	Root	Total
1	0.001	0.001	0.001	0.003
2	0.004	0.001	0.001	0.006
3	0.003	0.001	0.001	0.005
4	- 0.005	0.001	0.005	0.001
5	0.005	0.003	-0.001	0.007
6	0.001	0.004	0.015	0.020
7	-0.002	0.001	0.001	0.000
8	-0.004	0.001	0.005	0.002
9	0.010	-0.002	-0.002	0.010
10	0.001	-0.001	0.001	0.001
11	-0.009	-0.001	0.014	-0.024
12	-0.001	-0.003	-0.003	-0.007

Table 7.11: Rate of production (g/plant/day) of different component plant parts of *D. sissoo* seedling

Age (Months)	Leaf	Stem	Root	Total
1	0.001	0.003	0.001	0.005
2	0.001	-0.001	0.001	0.00
3	0.001	0.001	0.001	0.003
4	0.005	0.002	-0.001	0.006
5	-0.003	0.004	0.010	0.011
6	0.001	0.001	0.007	0.009
7	-0.004	0.002	0.003	0.001
8	0.010	0.001	0.004	0.0015
9	0.003	0.001	0.004	0.008
10	-0.007	-0.001	-0.007	-0.015
11	-0.001	-0.002	-0.001	-0.004
12	-0.003	-0.001	-0.009	-0.013

Table 7.12: Rate of production (g/plant/day) of different component plant parts of *T. arjuna* seedling

Age (Months)	Leaf	Stem	Root	Total
1	0.005	0.002	0.001	0.008
2	0.019	0.009	0.005	0.033
3	0.021	0.022	0.019	0.062
4	-0.017	0.002	0.015	0.000
5	-0.001	0.001	0.002	0.002
6	0.020	0.018	0.037	0.075
7	-0.002	-0.016	0.026	0.008
8	0.003	0.050	0.017	0.070
9	0.003	0.015	0.004	0.022
10	-0.023	-0.014	0.006	-0.031
11	-0.002	-0.053	-0.036	-0.091
12	-0.004	0.013	-0.020	-0.011

**Fig. 7.8 - Ratio of the different components weight to the total plant weight
at different age of seedlings of *Albizzia lebbek*, *Dalbergia sissoo*
and *Terminalia arjuna*.**

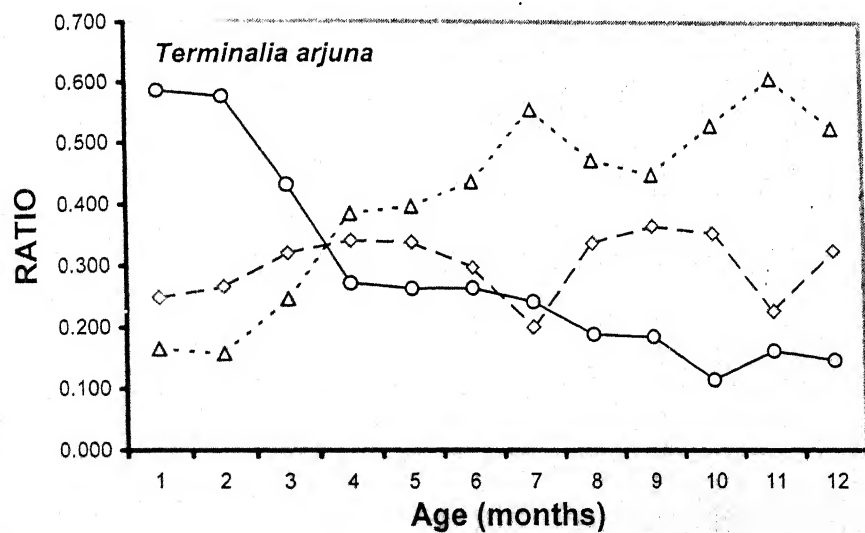
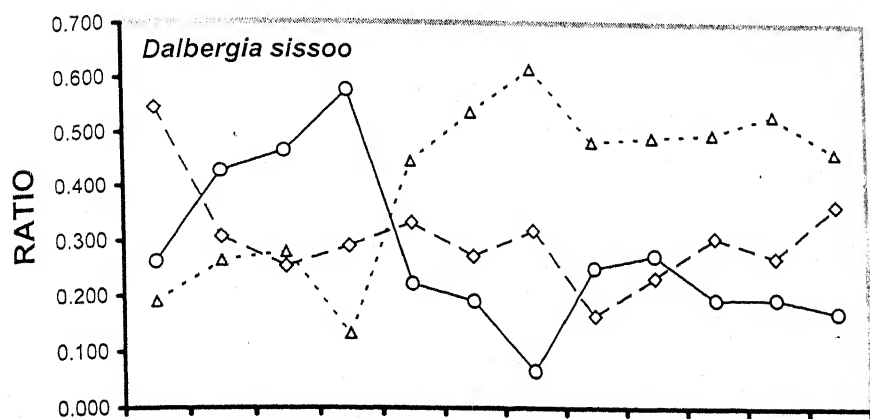
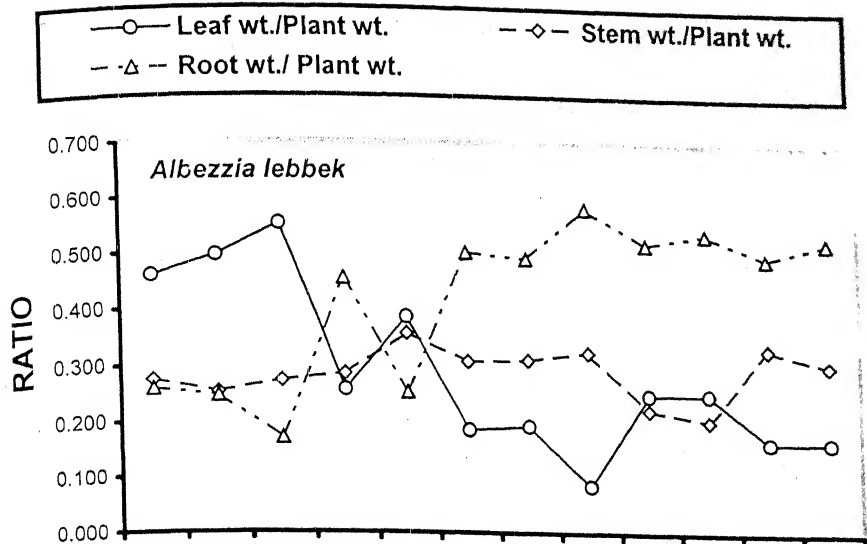
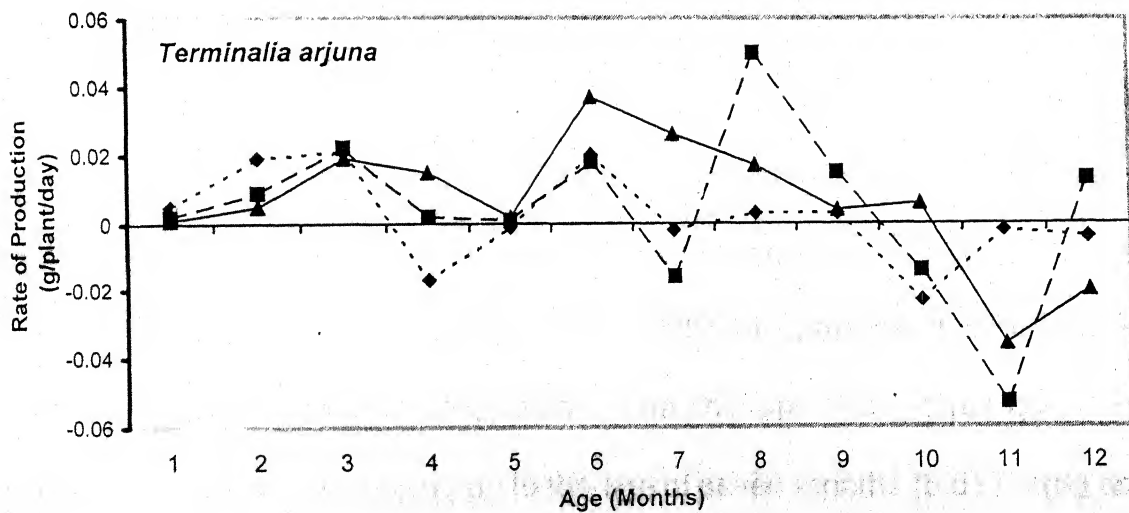
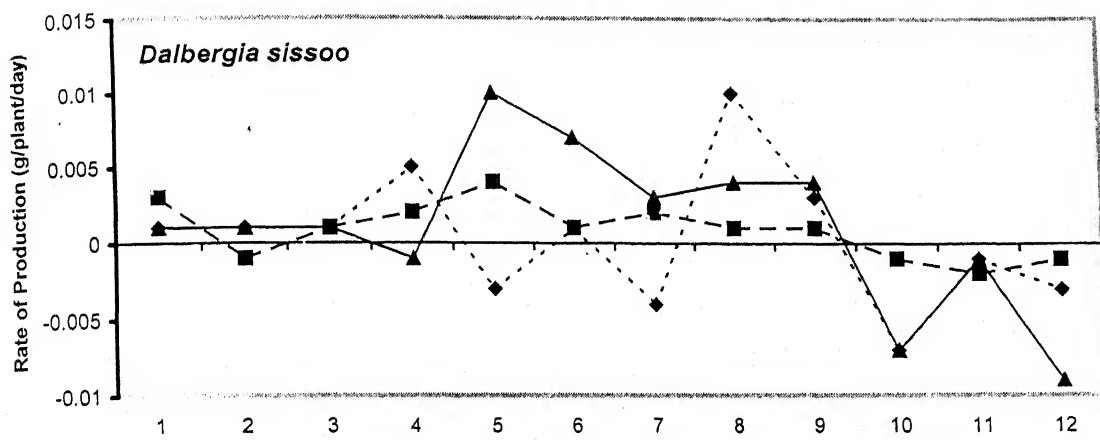
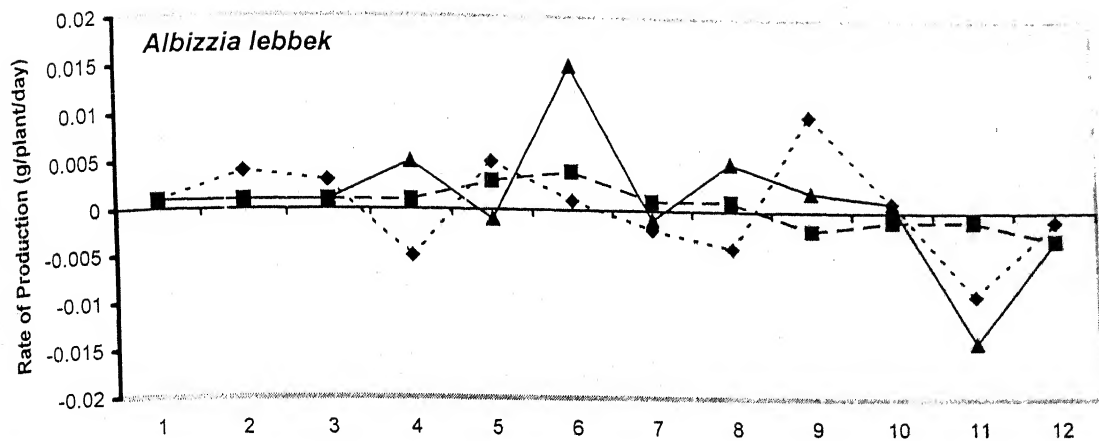


Fig. 7.9 - Rate of production in different components at different age of seedlings of *Albizzia lebbek*, *Dalbergia sissoo* and *Terminalia arjuna*.

---◆--- Leaf -■- Stem —▲— Root



Negative values are also recorded in all the three species.

LITTER PRODUCTION

The litter production by the three species upto the age of 12 months is presented in table 7.13. The total amount of organic matter returned to the soil by A. lebbek, D. sissoo and T. arjuna is 0.096, 0.129 and 0.757 g per plant respectively.

Table 7.13: Litter production in one year seedling of *A. lebbek*, *D. sissoo*, and *T. arjuna*

Species	Litter (g/plant)
<u>A. lebbek</u>	0.096
<u>D. sissoo</u>	0.129
<u>T. arjuna</u>	0.757

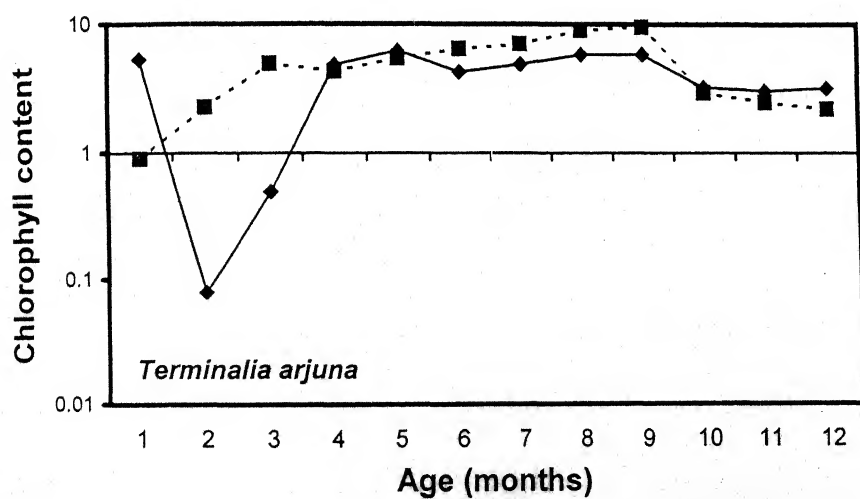
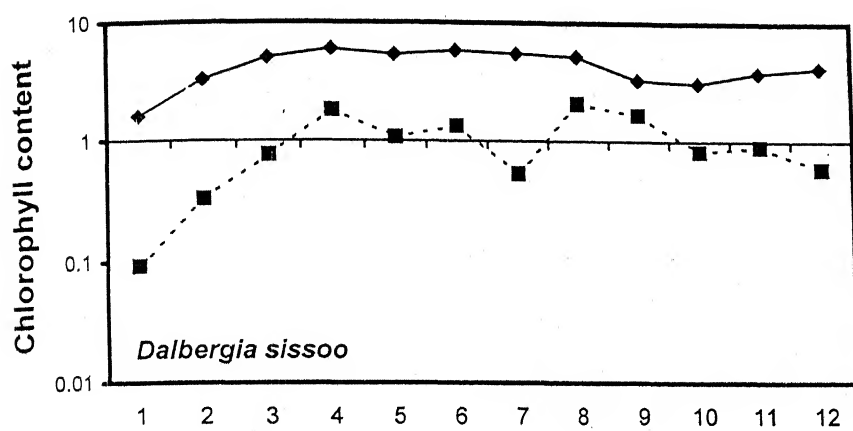
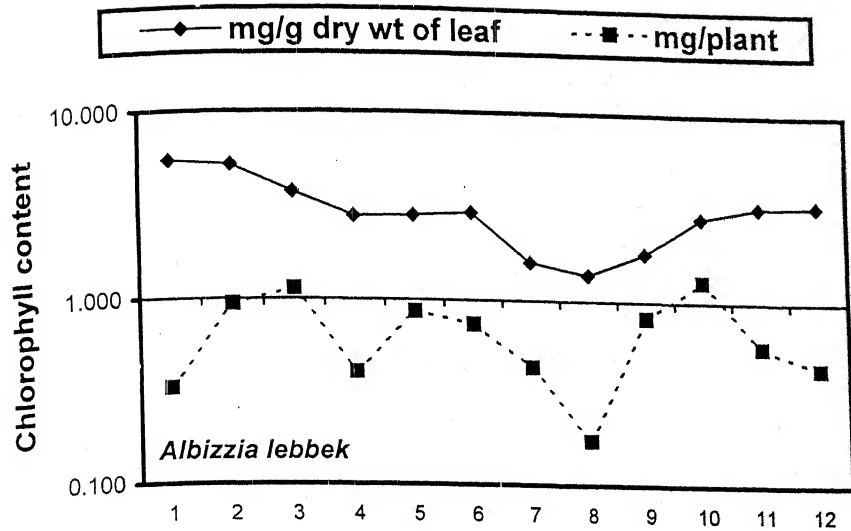
CHLOROPHYLL:

Chlorophyll content expressed on fresh weight basis is a reliable parameter for comparison. The data on the amount of chlorophyll per gram dry weight of leaf and the total chlorophyll per plant are presented in Table 7.14 and Fig. 7.10. All the species do not exhibit the same distribution pattern of chlorophyll on per unit weight basis. The chlorophyll is mg per gram dry weight increases in D. sissoo up to the age of seven months (6.512 mg/g dry weight) and then decreases but in T. arjuna no definite trend is observed. The

Table 7.14 : Chlorophyll content in seedlings of *Albizzia lebbek*, *Dalbergia sissoo* and *Terminalia arjuna* at different stages of their growth

Age (Months)	<i>A. lebbek</i>		<i>D. sissoo</i>		<i>T. arjuna</i>	
	mg/g dry wt. of leaf	mg/plant	mg/g dry wt. of leaf	mg/ plant	mg/g dry wt. of leaf	mg/ plant
1	5.519	0.331	1.610	0.093	5.305	0.901
2	5.249	0.944	3.301	0.330	0.079	2.284
3	3.769	1.138	5.102	0.765	0.498	4.925
4	2.819	0.405	6.011	1.815	4.847	4.313
5	2.852	0.864	5.410	1.076	6.199	5.442
6	2.960	0.740	5.801	1.334	4.275	6.403
7	1.605	0.436	5.512	0.533	4.899	7.015
8	1.385	0.174	5.210	2.073	5.834	8.949
9	1.823	0.820	3.311	1.662	5.831	9.504
10	2.855	1.296	3.103	0.822	3.263	2.943
11	3.260	0.573	3.810	0.906	3.048	2.493
12	3.319	0.438	4.210	0.589	3.194	2.210

Fig. 7.10 - Chlorophyll content in seedlings of *Albizzia lebbek*, *Dalbergia sissoo* and *Terminalia arjuna* at different age.



case of A. lebbek is just reverse of that of D. sissoo. The maximum amount of chlorophyll in this plant (5.519 mg/g dry weight) is recorded at the age of one month. It decreases upto the age of eight months (1.385 mg/g dry weight) and again it increases.

The maximum chlorophyll content of the seedling in T. arjuna is 9.504 mg per plant at the age of nine month but this value goes very low in A. lebbek being 1.296 mg per plant at the age of ten month and in D. sissoo it is just 2.073 mg per plant at the age of eight month.

CHAPTER - VIII

ENERGETICS

ENERGETICS

This Chapter deals with the energy fixation, accumulation and distribution in the individuals of different age groups of Albizzia lebbek, Dalbergia sissoo and Terminalia arjuna seedlings and in their seeds also.

According to Miller (1938) during seed germination heat is produced and the transformation and movement of foods from storage organs to the growing seedling takes place. Materials are digested in the storage organ and are moved to the growing points. There it is transferred into living or structural tissues that may differ markedly from the storage substance. The energy content of the seeds of A. lebbek, D. sissoo and T. arjuna is tabulated in Table 8.1.

Table 8.1: Energy content in fresh seeds of *A. lebbek*, *D. sissoo* and *T. arjuna*

Seeds	Energy content Cal / g dry wt.	Energy value (Cal / seed)
<i>A. lebbek</i>	4700.40	249.12
<i>D. sissoo</i>	3860.14	65.62
<i>T. arjuna</i>	4070.16	651.22

The efficiency with which the energy in the storage organs was moved to the growing parts of the seedling is estimated. This efficiency for A. lebbek, D. sissoo and T. arjuna seeds is 61.8, 84.3 and 93.3 per cent respectively.

STANDING STATE OF ENERGY IN PLANT BIOMASS

Energy content of A. lebbek, D. sissoo and T. arjuna seedling per gram dry weight of the leaves, stem and root of different age groups is presented in Tables 8.2, 8.3 and 8.4. It indicates that the caloric values vary widely among the plant parts and ranges between 2687 to 4949; 2732 to 5000 and 2003 to 4240 cal/g dry weight in A. lebbek, D. sissoo and T. arjuna respectively. The overall energy content of different plant parts shows that maximum energy per unit biomass tends to accumulate in the leaves followed in the decreasing order by root and stem in all the seedlings under study. When the age of the plant is also taken into consideration, the caloric value per unit weight does not exhibit any definite trend.

Tables 8.5, 8.6 and 8.7 present the values of energy storage of plant parts in A. lebbek, D. sissoo and T. arjuna seedlings. It indicates that energy storage per plant increases with increasing age of the seedlings. The maximum amount, 5.97 and 32.85 k cal / plant accumulates in the individuals of 09 months seedling of D. sissoo and T. arjuna respectively. In A. lebbek, maximum amount 6.85 k cal accumulates when the seedling was of 10 months age. The total energy values of plant parts i.e. leaves, stem and root also tend to increase with increasing age, in the seedling (Fig. 8.1, 8.2 and 8.3). In all the species root stored the maximum energy followed by stem and leaves (Table 8.5, 8.6 and 8.7).

Table 8.2: Energy value (Cal/g dry wt.) of different fractional plant parts of *A. lebbek* seedling at different stages of growth

Age (Months)	Leaf	Stem	Root	Average
1	3596	4134	3734	3821
2	3621	4851	4251	4241
3	3762	3527	3392	3560
4	4021	3332	4031	3795
5	4949	3744	3562	4085
6	4444	3874	4685	4334
7	4433	3506	3913	3951
8	4895	2737	3974	3869
9	3896	3912	3375	3728
10	4090	4191	3559	3947
11	3827	3908	3462	3732
12	3814	3345	3182	3447

Table 8.3: Energy value (Cal/g dry wt.) of different fractional plant parts of *D. sissoo* seedling at different stages of growth

Age (Months)	Leaf	Stem	Root	Average
1	3037	2732	3214	2995
2	3706	3069	3419	3398
3	4288	3271	4379	3979
4	5000	3772	3810	4194
5	4756	4153	3760	4223
6	3843	3677	3675	3732
7	3876	3555	3530	3654
8	3764	2992	2775	3177
9	3878	2973	3054	3302
10	3772	3226	3248	3415
11	3950	3575	3566	3697
12	4235	3591	3630	3819
Average	4008	3382	3505	3632

Table 8.4: Energy value (Cal/g dry wt.) of different fractional plant parts of *T. arjuna* seedling at different stages of growth

Age (Months)	Leaf	Stem	Root	Average
1	2571	2003	2036	2203
2	3927	2832	2848	3202
3	3360	3146	3855	3454
4	3670	3641	4028	3780
5	3998	3593	3953	3848
6	4175	3689	4084	3983
7	3945	3547	3937	3810
8	3867	3590	3770	3742
9	3978	3584	3762	3775
10	4098	3711	3699	3836
11	4240	3824	3856	3973
12	4221	3878	3799	3966
Average	3837	3420	3635	3631

**Table 8.5: Energy contents (K Cal/plant) of different plant parts of
A. lebbek seedling at various stages of growth**

Age (Months)	Leaf	Stem	Root	Total
1	0.21	0.15	0.13	0.49
2	0.65	0.45	0.38	1.48
3	1.14	0.53	0.25	1.92
4	0.58	0.53	0.81	1.92
5	1.50	1.05	0.71	3.26
6	1.11	1.60	3.14	5.84
7	1.20	1.53	2.70	5.43
8	0.62	1.30	3.38	5.30
9	1.75	1.57	3.14	6.46
10	1.86	1.55	3.44	6.85
11	0.67	1.37	1.81	3.85
12	0.50	0.81	1.32	2.63

**Table 8.6: Energy contents (K Cal/plant) of different plant parts of
D. sissoo seedling at various stages of growth**

Age (Months)	Leaf	Stem	Root	Total
1	0.18	0.33	0.13	0.64
2	0.37	0.22	0.21	0.80
3	0.64	0.27	0.39	1.30
4	1.51	0.57	0.27	2.35
5	0.95	1.24	1.50	3.69
6	0.88	1.20	2.36	4.44
7	0.32	1.39	2.67	4.38
8	1.50	1.26	2.11	4.87
9	1.95	1.28	2.75	5.98
10	0.10	1.34	2.19	3.63
11	0.94	1.17	2.30	4.41
12	0.59	1.07	1.37	3.03

Table 8.7: Energy contents (K Cal/plant) of different plant parts of
T. arjuna seedling at various stages of growth

Age (Months)	Leaf	Stem	Root	Total
1	0.44	0.14	0.10	0.68
2	2.91	0.97	0.57	4.45
3	4.73	3.29	3.09	11.11
4	3.27	4.06	5.07	12.40
5	3.51	4.04	5.22	12.77
6	6.25	6.23	10.11	22.59
7	5.65	4.22	12.88	22.75
8	5.93	9.84	14.42	30.19
9	6.48	11.50	14.87	32.85
10	3.70	10.26	15.31	29.27
11	3.47	4.39	11.78	19.64
12	2.92	5.93	9.38	18.23

Fig. 8.1 - Energy value of different fractional plant parts at different age of seedlings of *Albizzia lebbek*.

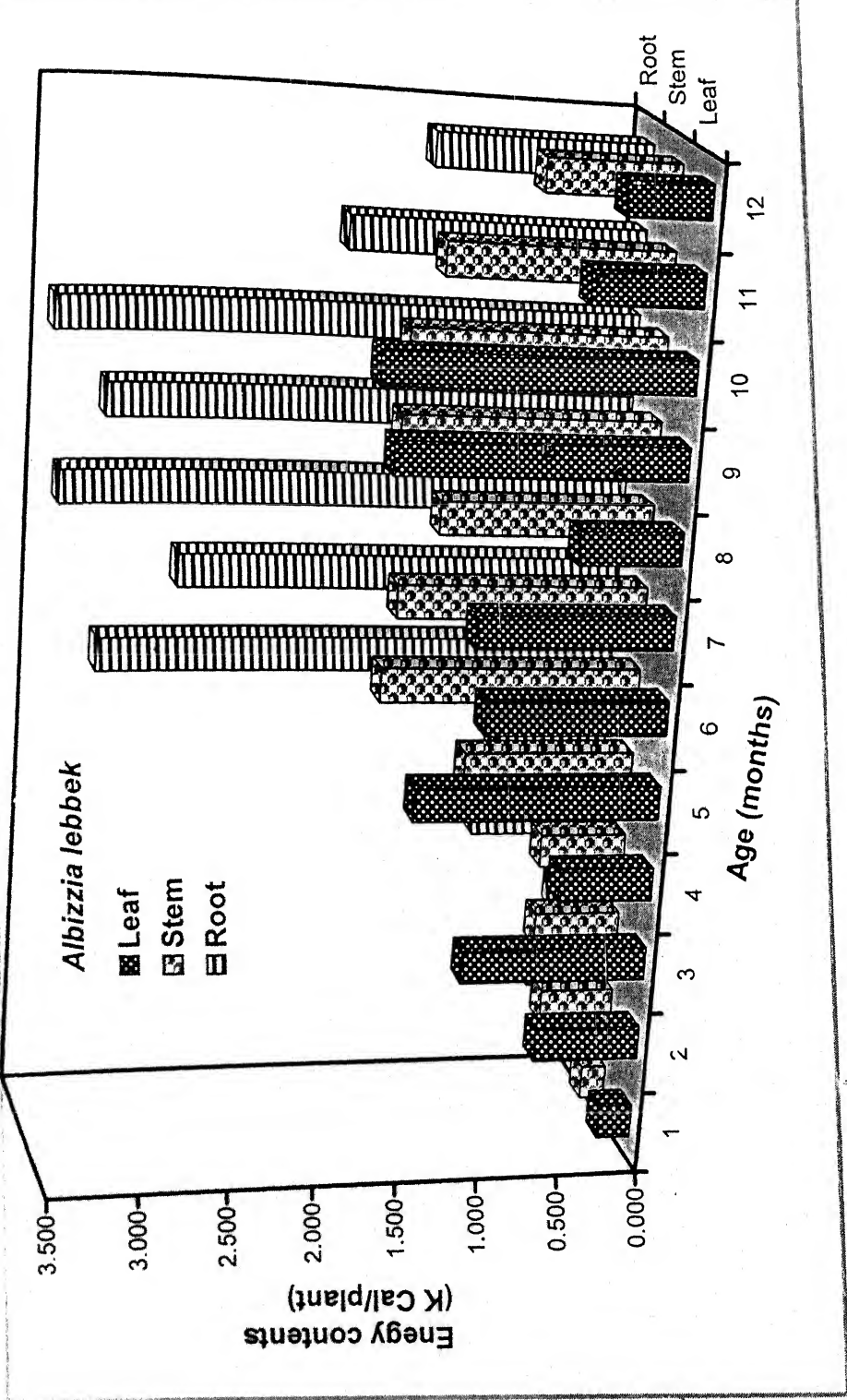


Fig. 8.2 - Energy value of different fractional plant parts at different age of seedlings of *Dalbergia sissoo*.

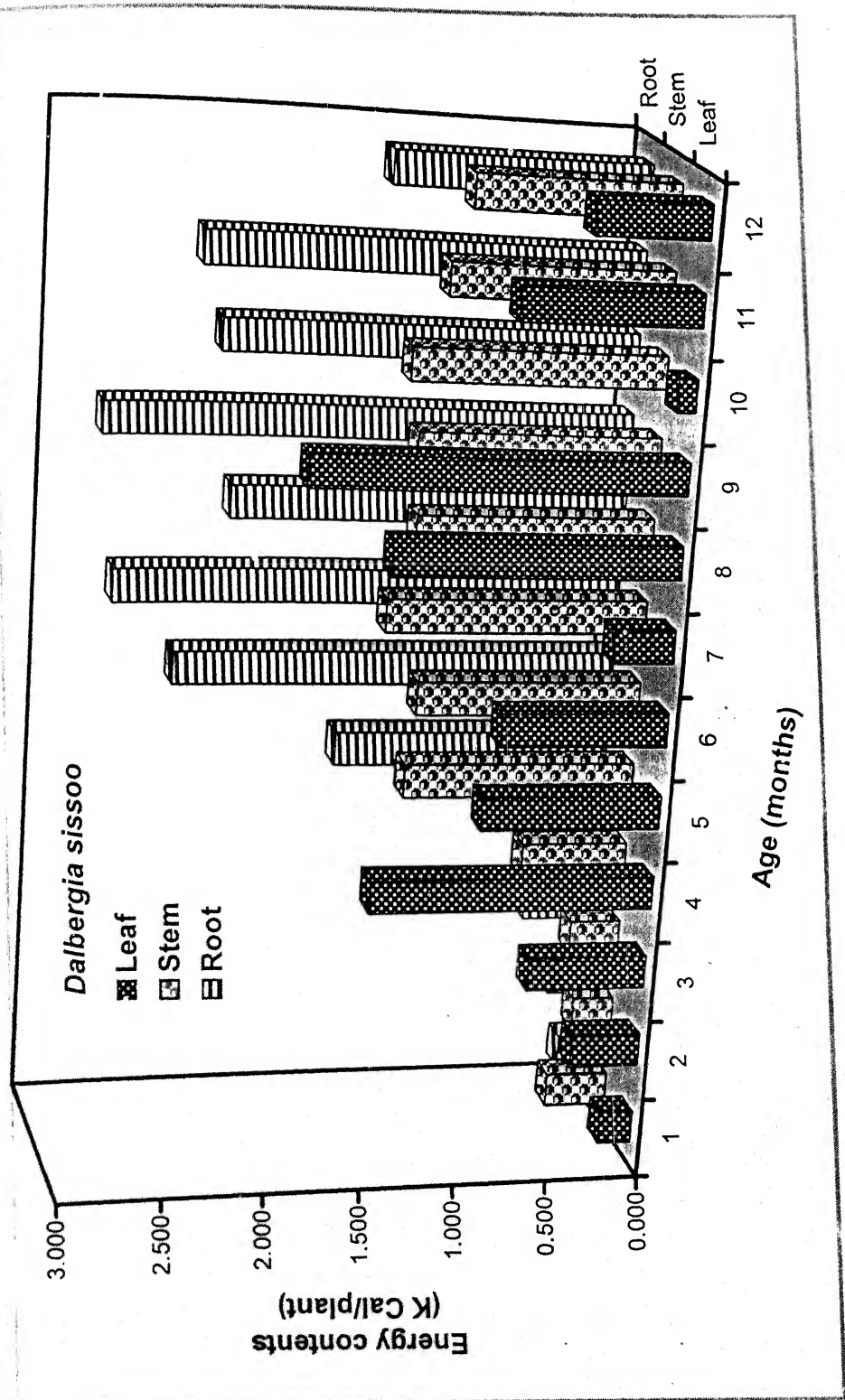
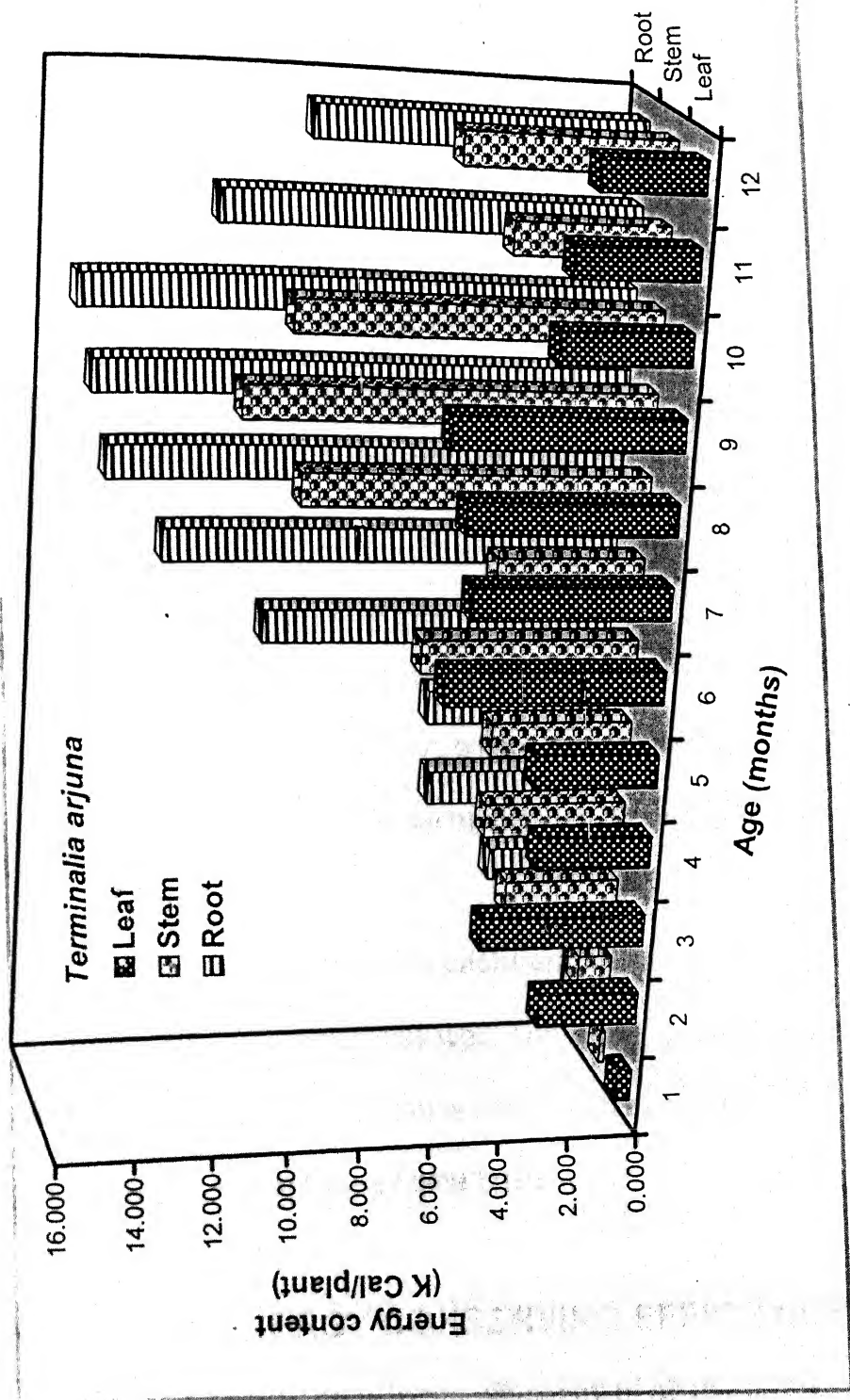


Fig. 8.3 - Energy value of different fractional plant parts at different age of seedlings of *Terminalia arjuna*.



ENERGY CONSERVING EFFICIENCY

Conserving efficiency of primary producers is the ratio of output (calories captured by the plants) to input (solar radiation) in an unit area over a definite length of period.

In the investigation only half the solar radiation has been considered for calculating energy conserving efficiency, because approximately 50 per cent of the total radiation (ultra-violet and infra-red portion of the spectrum) is not usable in photosynthesis (Daubenmire, 1959; Terrin et al., 1957).

With the help of the harvest method only the energy conserving efficiency of the plants can be calculated, therefore, the net dry matter production per m^2 as obtained during different sampling period was converted into energy value of the (k cal/m^2) by multiplying them with the caloric value of the plant materials.

The green shoot only captures the energy but the material so built is distributed to other parts as well. Therefore, in order to get the energy conserving of the total plant biomass (Root + stem + leaves) has been taken into consideration on unit area / time basis.

VARIATION IN ENERGY CONSERVING EFFICIENCY

The energy conserving efficiency of all the three plant species vary considerably both in the period and extent as apparent from the study of Table 8.8. The maximum value of 0.058, 0.131 and 0.222 per cent in August

Table 8.8: Energy conserving efficiency (%) of *A. lebbek*, *D. sissoo* and *T. arjuna* seedlings at different stages of growth

Age (Months)	Species		
	<u>A. lebbek</u>	<u>D. sissoo</u>	<u>T. arjuna</u>
1	0.009	0.013	0.013
2	0.019	0.003	0.072
3	0.008	0.008	0.118
4	0.001	0.021	0.025
5	0.027	0.027	0.007
6	0.058	0.131	0.222
7	-0.009	-0.001	0.003
8	-0.012	0.009	0.168
9	0.031	0.029	0.071
10	0.011	-0.041	-0.026
11	-0.082	-0.003	-0.265
12	-0.031	-0.035	-0.036

has been recorded for A. lebbek, D. sissoo and T. arjuna respectively. Naturally negative values of efficiency are obtained where the net production values are in negative. The negative values are recorded in the months of September, October, January and February in case of A. lebbek and September, December, January and February in case of D. sissoo. But in case of T. arjuna the negative values were recorded in the months of December, January and February.

Thus on the whole the average annual energy conserving efficiency by T. arjuna (0.058%) is four times greater than A. lebbek (0.014%) and about three times greater than D. sissoo (0.020%).

ENERGY RELEASED

Energy content (k cal) of litter of A. lebbek, D. sissoo and T. arjuna is presented in Table 8.9. The total amount of energy added to the soil through the litterfall by A. lebbek is 0.480 k cal per plant, whereas, D. sissoo and T. arjuna seedlings added 0.510 and 2.687 k cal per plant respectively. Energy content of litter of A. lebbek, D. sissoo and T. arjuna is 5.01, 3.95 and 3.55 k cal per gram dry weight respectively (Table 8.9).

Table 8.9: Caloric value and total amount of energy added to soil with the litterfall of *A. lebbek*, *D. sissoo* and *T.arjuna* seedlings

Species	K cal / g	K cal / plant
A. lebbek	5.01 ± 0.88	0.480
D. sissoo	3.95 ± 0.22	0.510
T. arjuna	3.55 ± 0.30	2.687

CHAPTER - IX

MINERAL STATUS

MINERAL STATUS

The present chapter involves the uptake, accumulation and retention of nitrogen and phosphorus in plant parts and their return to the soil with the litterfall of the seedling of Albizzia lebbek, dalbergia sissoo and Terminalia arjuna.

The results of the chemical analysis for nitrogen and phosphorus of seeds of A. lebbek, D. sissoo and T. arjuna are presented in Table 9.1. These shos that the amount of nitrogen and phosphorus stored in the seed of T. arjuna is maximum among the species studied.

Table 9.1: Total nitrogen and phosphorus content (mg/seed) of the seeds of *A. lebbek*, *D. sissoo* and *T. arjuna*

Seed	Nitrogen	Phosphorus
<i>A. lebbeek</i>	0.799	0.275
<i>D. sissoo</i>	0.459	0.081
<i>T. arjuna</i>	3.200	0.960

ACCUMULATION OF NITROGEN AND PHOSPHORUS IN PLANT BIOMASS:

The total nitrogen, accumulated in plant parts, has been computed and the data for different species under study are presented in Table 9.2.

The total nitrogen content in plant parts as well as per plant

Table 9.2: Accumulation of nitrogen (mg/plant) in component plant parts of different age group of *Albizia lebbek*, *Dalbergia sissoo* and *Terminalia arjuna* seedling

Age (Months)	<u>A. lebbek</u>			<u>D. sissoo</u>			<u>T. arjuna</u>		
	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
1	0.209	0.089	0.102	0.696	1.080	0.546	2.040	0.504	0.240
2	0.720	0.230	0.286	1.500	0.864	1.054	11.130	3.078	1.414
3	2.114	0.418	0.376	2.731	1.230	1.845	21.120	10.460	7.218
4	1.296	0.496	1.143	5.134	2.220	1.400	15.130	12.276	17.136
5	4.569	0.980	1.194	3.383	5.066	8.778	10.536	11.260	15.864
6	3.000	1.318	6.164	3.910	8.829	9.645	25.466	20.280	24.760
7	2.992	1.534	8.280	1.640	7.840	16.676	28.640	13.090	49.080
8	1.512	1.666	11.928	10.746	6.140	15.240	26.078	32.880	45.912
9	5.400	2.211	12.090	10.040	4.300	15.030	24.450	38.520	47.424
10	3.632	1.184	5.324	3.975	5.004	11.424	13.530	35.945	45.540
11	1.056	1.408	2.610	3.570	3.936	9.660	9.610	13.776	33.594
12	0.924	0.968	3.328	2.377	3.576	5.670	8.304	18.360	24.700

increases with age (Table 9.2). An overall pattern of distribution of nitrogen in the plant body indicates its maximum accumulation in the root followed by leaves and stem in case of A. lebbek but in case of D. sissoo and T. arjuna it is followed by stem and leaves (Table 9.2 and Fig. 9.1, 9.2 and 9.3)

The data of the total phosphorus of the seedling under study are presented in Table 9.3 (Fig. 9.1, 9.2 and 9.3) and the analysis shows more or less the same trend as in the case of nitrogen already recorded.

The total phosphorus content in different plant parts shows that maximum accumulation takes place in root followed by stem and leaves (Table 9.3).

RETURN OF NITROGEN AND PHOSPHORUS TO THE SOIL WITH THE LITTERFALL.

The nitrogen and phosphorus contents of the litter during 1999-2000 of A. lebeek, D. sissoo and T. arjuna seedlings are furnished in Table 9.4.

Table 9.4: Total nitrogen and phosphorus content (mg/plant) of litter of *A. lebbek*, *D. sissoo* and *T. arjuna* seedlings

Species	Nitrogen	Phosphorus
<i>A. lebeek</i>	1.440	0.278
<i>D. sissoo</i>	3.225	0.286
<i>T. arjuna</i>	5.495	2.104

The total return of nitrogen and phosphorus with the litterfall during

Table 9.3: Accumulation of phosphorus (mg/plant) in component plant parts of different age group of
Albizzia lebbek, *Dalbergia sissoo* and *Terminalia arjuna* seedling

Age (Months)	A. lebbek			D. sissoo			T. arjuna		
	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
1	0.12	0.117	0.102	0.081	0.297	0.202	0.255	0.360	0.192
2	0.54	0.368	0.295	0.160	0.190	0.186	1.054	1.368	0.808
3	0.936	0.570	0.341	0.318	0.302	0.315	2.112	4.184	2.807
4	0.475	0.592	0.965	0.664	0.502	0.210	0.890	4.464	4.410
5	1.475	0.868	0.895	0.537	0.796	1.117	1.493	5.067	3.305
6	0.875	1.977	3.484	0.485	0.752	1.736	2.996	5.915	6.190
7	0.952	0.734	3.312	0.180	0.929	1.289	2.864	3.570	4.908
8	0.504	0.618	3.493	1.074	0.924	1.143	2.347	10.960	4.974
9	1.426	0.442	2.790	0.753	1.290	0.990	2.445	14.445	7.904
10	1.180	1.221	2.129	0.198	0.141	0.879	1.624	13.825	10.350
11	0.299	1.222	0.939	0.357	0.229	1.030	1.636	5.969	7.635
12	0.290	0.892	1.456	0.210	0.354	0.643	1.315	9.180	6.175

Fig. 9.1 - Total nitrogen and phosphorus in different components of different age of *Albizzia lebbek* seedling.

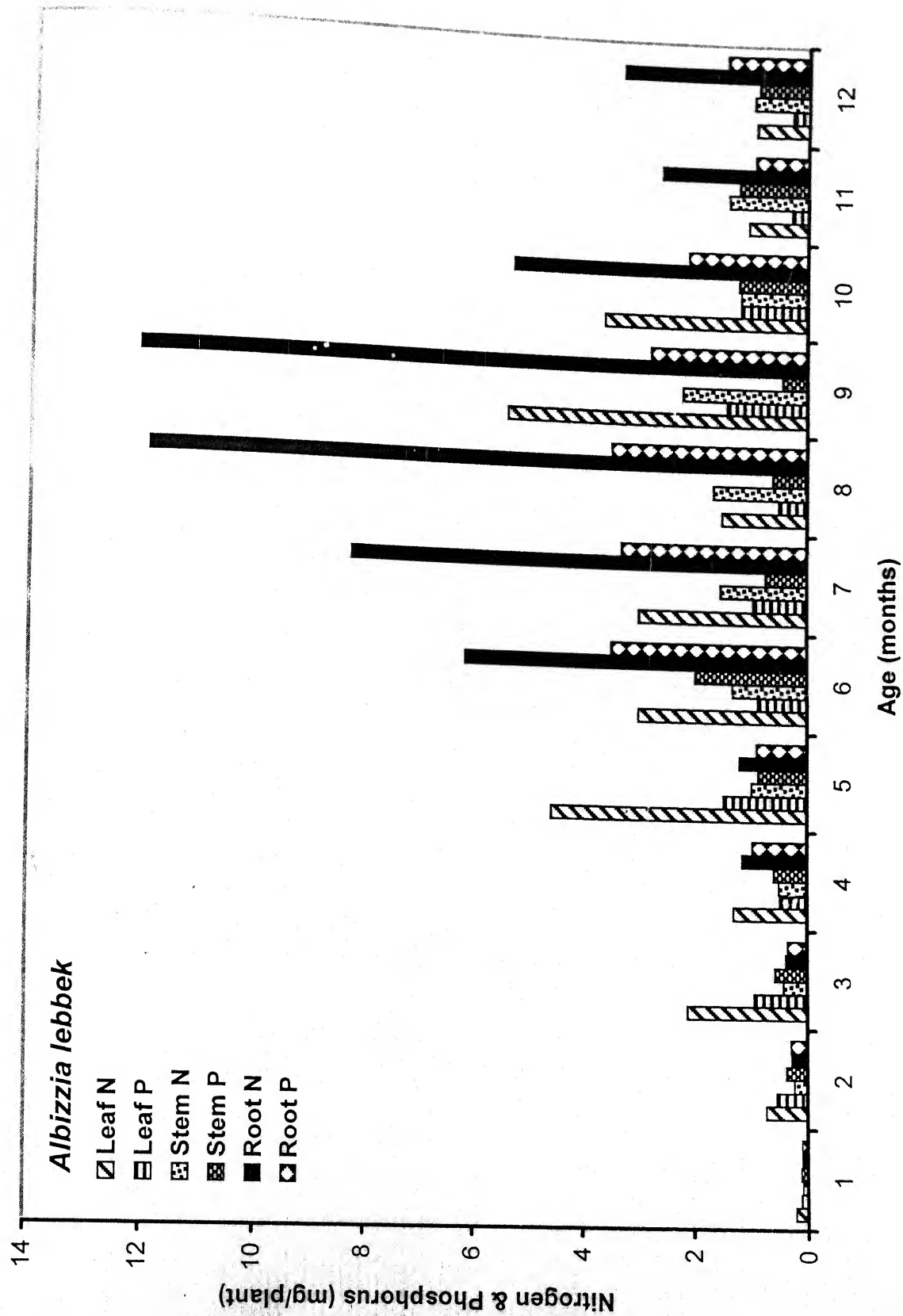


Fig. 9.2 - Total nitrogen and phosphorus in different components of different age of *Dalbergia sissoo* seedling.

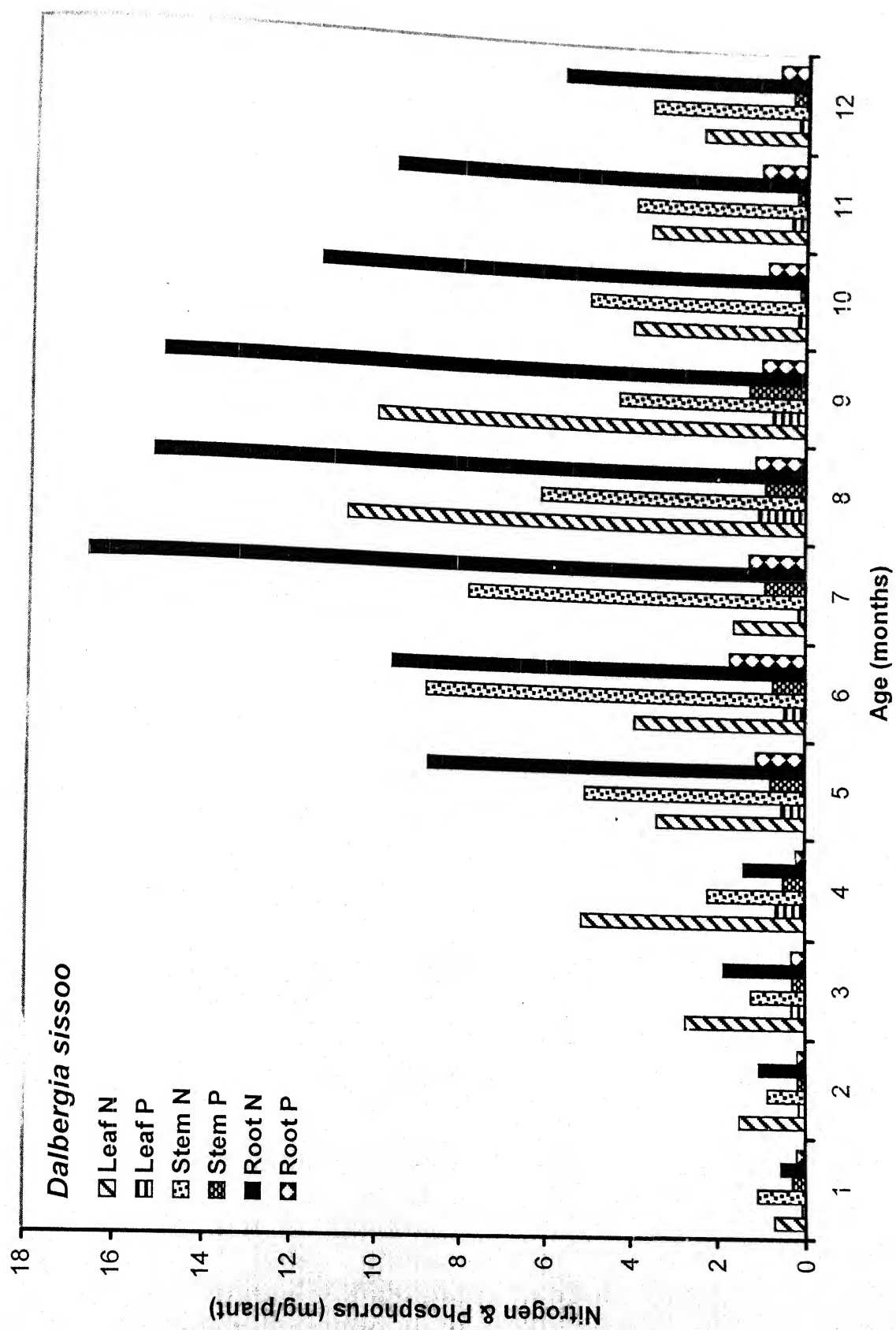
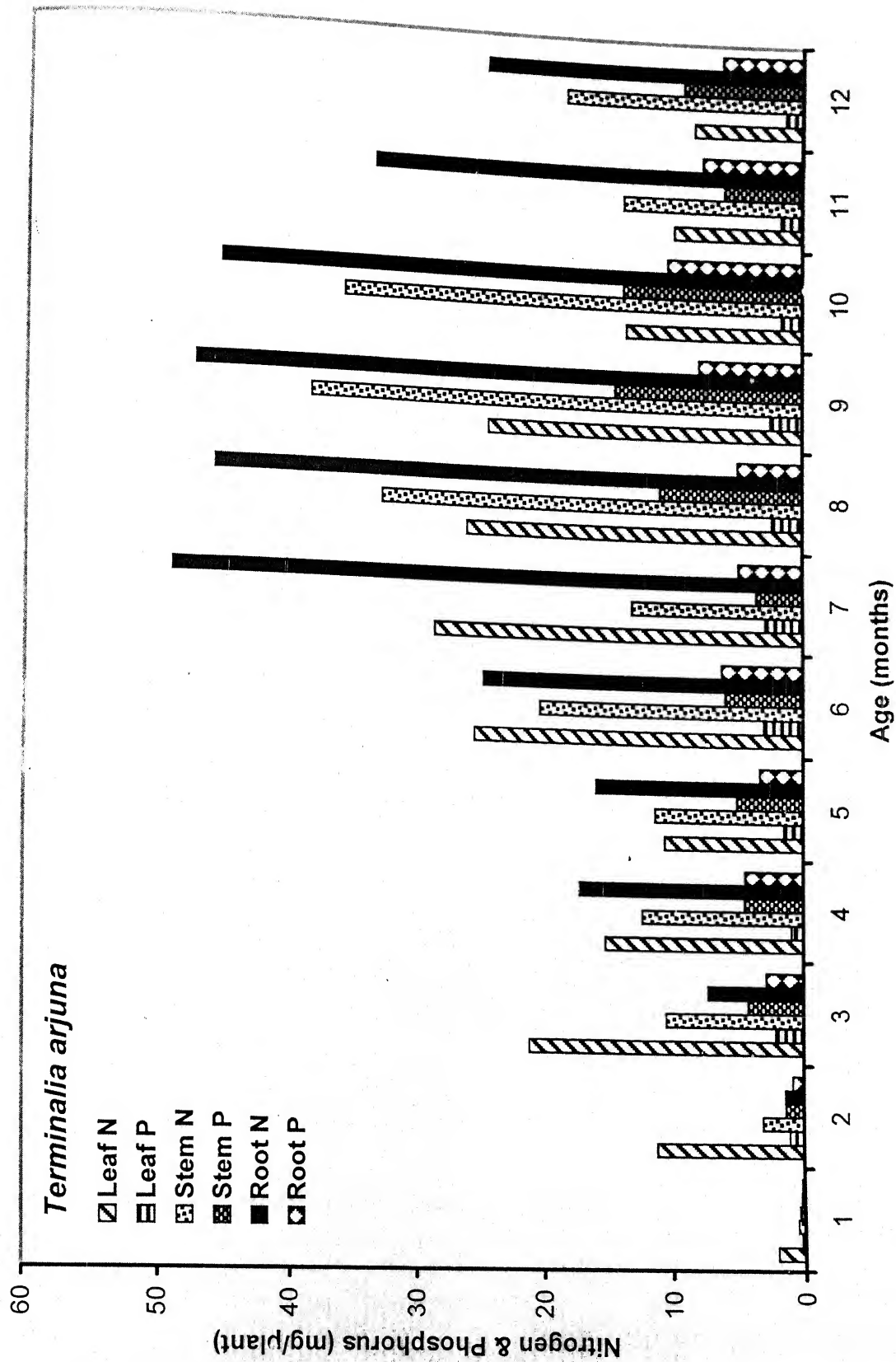


Fig. 9.3 - Total nitrogen and phosphorus in different components of different age of *Terminalia arjuna* seedling.



1999-2000 in A. lebbek is 1.440 and 0.278 mg/plant respectively. But D. sissoo and T. arjuna release nitrogen 3.225 and 5.495 mg per plant and phosphorus 0.286 and 2.104 mg/per plant respectively.

CHAPTER - X

DISCUSSION

DISCUSSION

SEED GERMINATION

The germination is significantly affected by light temperature and pH in all the three species.

The influence of light on germination has been termed 'photoblastism' by Evenari (1956). Negbi and Kaller (1964) observed that germination of seeds is generally promoted by one region of the spectrum and inhibited by the other region. In Albizzia lebbek the germination is accelerated by high energy region of the visible spectrum (blue light). In Negella, Isikawa (1957) has also observed that long irradiation with blue light stimulates the germination. In the development of fern gametophyte brief and longer periods of irradiation bring about different types of growth. Blue and far red light both promote filament elongation (Miller and Miller, 1964). It seems that in Terminalia arjuna the brown colour of seeds is responsible for inhibition of germination under the action of blue and red light. Barton (1962) has drawn attention to the fact that different germination behaviour of brown/black seeds of Halogeton glomeratus may also show the effect of seed coat colour on germination of seeds Anagallis arvensis. Kadman - Zahavi (1960) attributed the lack of blue effect in the germination of Amaranthus retroflexus seed may be due to the black seed coat which does not transmit the shorter wavelengths.

All the time uniform temperature seems to be effective only in Dalbergia sissoo. However, diurnal alternating temperature as found in nature

(in the room) gives better germination in all the three species. It has been observed by Tool et al. (1953), Cohen (1958) and Newman (1963) that the germination of seed is higher under diurnal alternating temperature than under uniform temperature. The mean maximum and minimum temperature records of Orai (Table 3.1) show that the maximum temperature ranges from 14 to 43°C, while the minimum varies from 9 to 28°C, the difference between the two being 5 to 15°C. During germination, in natural habitats, the maximum temperature varies from 32 to 40°C and the minimum 25 to 28°C, i.e. the germination is during the warm summer.

The pH of the medium is an important edaphic factor for the germination of seeds. It is found that different soil pH has varied effect on the germination of the plant. The range of 5.5 to 7.0 pH is suitable for germination in all the species under study. In natural conditions, in forest, from where seeds were collected for study, soil pH ranges from 6.6 - 6.8 (Sharma, 1971) which is found suitable for better germination of the seeds of the species. It is clear from Fig. 5.1B that any change towards acidic or basic side reduces the percentage germination. Mayer et al. (1960) reported that enzymatic activities controlled the germination process. The activity of an enzyme appears to be at its maximum at a certain optimum hydrogen ion concentration, but it decreases usually on either side of this value. Devlin (1966) has observed that at higher or lower pH values than the suitable range, the enzymes are inactivated. Hence, on pure acidic medium, pH 2, no germination took place in any of the three species.

GROWTH ANALYSIS OF THE SEEDLING

There is no significant difference in the pattern of RGR, NAR and MLWR within each of the species. The RGR of T. arjuna is considerably higher than that of the A. lebbek and D. sissoo. It is due to high NAR. The high rate of NAR in all the three seedlings under the study is due to low rate of respiration during rainy and winter season, because of low temperature during night and day (Table 6.1). Fernandes (1923) reported that due to decreased respiration rate in pea seedling at low temperate, the NAR value increases.

With increasing age reduction in chlorophyll and water content of photosynthetic part seems to decrease NAR and take it down to negative balance. As reported, the negative value of RGR is due to the negative value of NAR. Thorne (1960) reported that NAR, RGR and leaf area fall with time at similar rate in potato, sugarbeet and barley. Watson (1952) describing physiological basis of variation in yield of crops and Woledge and Jeuiss (1969) working with tall fescue (Festuca arundinacea Scrub.) reported that the rate of photosynthesis decreases with increasing age. This degradation of metabolic activity causes senescence, which leads to drastic reduction in gross photosynthesis vis-a-vis energy trapping capacity and result in negative balance of NAR. In the present study the litterfall in all the species took place when the negative value of NAR and RGR was observed. Das (1968) reported that the green colour of bean leaves decreases with advancing age followed by reduced NAR.

A comparison of the values of MLWR and NAR shows that the highest MLWR had the lowest rate of NAR. Thus a reciprocal relationship between NAR and MLWR is recorded (Fig 6.1, 6.3). Such negative correlation has been previously reported in literature (Watson, 1958); Pollaerd and Waering, 1968). Watson (1958) suggested that a high degree of mutual shading of the leaves reduces NAR. Such a suggestion may, infact, explain some of the negative correlation between NAR and MLWR. But the full explanation of this relationship has a more complex basis. It can be interpreted in view of the recent knowledge of the effects of plant growth on photosynthetic rates. Sweet and Waering (1968) postulated a relationship between the amount of leaf which a plant carries and the demands made on that leaf for photosynthesis. NAR has been shown to vary with the demands made upon the leaf for assimilation. Thus, Nosberger and Humphries (1965) observed that NAR was significantly higher in potato plants which were bearing tubers, than in those from which tubers had been removed. Similar results have been obtained for fruiting and non-fruiting apple trees (Maggs, 1963). It is possible that in plants with lower MLWR the demand for assimilates made on each unit of leaf is greater than in plants with a higher MLWR. According to Went (1958) such difference in demand may be expected to affect the rate of photosynthesis. An increased demand for assimilates leads to a faster removal of metabolites from the leaves and a higher photosynthetic rate. Sorersen (1964) gave a similar interpretation to explain the negative correlation and more recent work (Nosberger and Thorne, 1965) is available to support such

a view. However, the problem of the interrelationship between growth and photosynthesis is not simple, and it is possible that with further work such a hypothesis may require modification.

BIOMASS AND PRODUCTIVITY:

The results reveal that the dry weight of plant parts as well as the whole seedling increases with the age in all the three species. Corresponding the growth of plant at various age the chlorophyll content was found maximum in Terminalia arjuna and Dalbergia sissoo at the age of nine months. In Albizia lebbek the maximum value was recorded at the age of ten months.

It is generally accepted that in outdoor experiments plants attain maximum rate of photosynthesis at light intensities below full sunlight (Kramer and Clark, 1947; Donald, 1961). Therefore, in rainy season, when light is interrupted by the cloud and other factors like moisture content in the air causing proper and efficient distribution of light on foliage, maximum production is obtained. Following the same the high dry matter accumulation is attained in the month of July in case of D. sissoo and in the month August in case of A. lebbek and T. arjuna.

According to Lieth (1971) the difference in productivity, in all the regions of the world is caused primarily by environmental conditions. A careful consideration of environmental controls of the primary production is, therefore, essential for model building and for the full understanding of the productive process.

During winter season the value of dry matter production was reduced and it even reached negative values in all the three species. The explanation of this negative production is that with increasing age in seedlings, reduction in light interception and chlorophyll content of photosynthetic parts also seem to decrease NAR and take it down to negative balance (Chapter VI.). According to Watson (1952) the reduction in NAR may be caused by competition for light, CO_2 water and mineral elements among leaves. This reduction in NAR may cause the degradation of metabolic activity leading to senescence. In the present study the chlorophyll content decreases proceeding litterfall in the months of January and February. It causes reduction in photosynthesis rate of seedlings. Brougham (1960) obtained maximum positive correlation between chlorophyll and photosynthesis, therefore, it reduces gross assimilation below the value of respiration. Ultimately the negative balance of production is quite possible. Much emphasis has recently been laid on the relationship between the chlorophyll content and net production of organic matter by the plants varies throughout the season.

In studies of plant growth in relation to environment, growth is always characterised by the ratio between dry weight of root and shoot. This ratio is lower in the younger seedlings in all the species which means that the younger plants greater organic matter tends to accumulate in the above ground parts. As the plant matures much of the photosynthate is directed towards underground parts. Hence, greater amount of organic matter accumulates in non-photosynthetic plant parts. In old trees of the dry deciduous forest, organic

matter accumulation is shown by Misra (1969) to be higher in the bole and less in the root. This ratio can therefore depend on the overall rate of plant growth. The causal relationship between these two properties is not always clear. Ratio of the leaf weight and total plant dry weight also changes during plant growth. Table 10.1 Compares the standing crop biomass and litter production of *A. lebbek*, *D. sissoo* and *T. arjuna* seedlings. The litter of *A. lebbek*, *D. sissoo* and *T. arjuna* contributes lesser amount of the net production.

Table 10.1: Comparative account of standing crop biomass and litterfall (g/plant) of *A. lebbek*, *D. sissoo* and *T. arjuna* seedlings up to the age of 12 months

Biomass fraction	Species		
	<i>A. lebbek</i>	<i>D. sissoo</i>	<i>T. arjuna</i>
Leaves	0.132	0.140	0.692
Stem	0.242	0.298	1.530
Root	0.416	0.378	2.470
Total	0.790	0.816	4.692
Litterfall	0.096	0.129	0.757

Further analysis of the data presented in this chapter, yield following interesting trends in the standing crop biomass and productivity and also the chlorophyll content increase with the age of seedlings except for a few months when the seedlings are affected by litterfall and the negative balance is obtained in all the three species.

ENERGETICS

The most critical phase in the life cycle of a plant is its seedling stage (Misra and Puri, 1954). During germination and early growth of the embryo the food reserved of the seed is utilized. The present study indicates the efficiency with which the energy is in the storage organ is moved to the growing seedlings in seedling of A. lebbek, D. sissoo and T. arjuna. This efficiency is higher in T. arjuna probably due to large size and weight of the seed, as compared with the other species under study. Hence, heavy and larger seeds with greater amount of stored food have a better chance of producing surviving seedlings.

According to Ovington and Heitkamp (1960) the amount of solar energy stored in plant biomass depends upon the kind of tree species and its age. It is evident from the data presented in chapter VIII that the seedlings of different species of dry deciduous forest at Orai Division differ in their energy content. The energy content (Cal/g) of the fractional plant parts of all the species under study varies widely and exhibits a trend similar to that of Shorea robusta and Buchanania lanzan trees of dry deciduous forest (Sharma, 1971). In the latter also leaves contain maximum energy per unit weight followed by root and stem. Hadley and Bliss (1964) have reported higher calorific values for shoots as compared to underground parts. In the present study the energy content of roots is lower than that of leaves but more than that of stem. Thus the situation in the seedlings under study is the same of the presentation of Hadley and Bliss (1964).

The seedlings being equipped with more efficient assimilatory organs have a higher energy content in their leaves. According to Dwivedi (1970) age of the plant affects the accumulation and synthesis of organic substance, which may finally affect the caloric content of plants. As the plant advances in age, energy content of the leaves also increases with age, except in few months when the seedlings are affected by litterfall.

Most of the source of energy available to man depend upon sunlight. The relative efficiencies, with which different plant communities convert solar energy to chemical energy, is of primary importance. The solar energy conserving efficiency of A. lebbek, D. sissoo and T. arjuna seedlings vary considerably. The overall values of energy conserving efficiency indicate that T. arjuna is a better energy conserver. (0.058%) than D. sissoo (0.02%) and A. lebbek (0.014%). On comparison of energy conserving efficiency of seedling with Shorea robusta (0.09%) and Buchanania lanzan (0.03%) trees (Sharma, 1971), it may be concluded that seedlings are better energy conserver than the trees.

The net annual primary production increases with the plant age. It is directly related with the energy conserving efficiency in A. lebbek, D. sissoo and T. arjuna seedlings.

A comparative account of energy trapped and released has been presented in Table 10.2. It indicates that in T. arjuna seedling, energy accumulation, retention in the form of organic matter and release with the litterfall is several times greater than those of D. sissoo and A. lebbek.

Table 10.2: Comparative account of energy trapped and released (K Cal/ plant) by *A. lebbek*, *D. sissoo* and *T. arjuna* seedlings

	<i>A. lebbek</i>	<i>D. sissoo</i>	<i>T. arjuna</i>
Net energy accumulated			
Above ground	1.59	2.17	11.54
Underground	1.32	1.37	9.38
Total energy released			
with litter fall	0.48	0.51	2.69
Energy retained			
Above ground	1.11	1.66	8.85
Under ground	1.32	1.37	9.38

MINERAL STATUS

Nitrogen is an essential constituent of proteins which are at the base of all the life processes. Table 9.1 indicates that the seeds are rich in nitrogen. According to Crocker and Barton (1953) protein gives a very usable form of storage for the growing seedling. With the hydrolysis of the protein to amino acid the carbon chains releasing energy on oxidation new nitrogen compounds are synthesised.

The circulation of minerals in woodland ecosystem is not a closed one but the mineral capital fluctuates as when the elements are removed or added. Figures for the accumulation and retentions of nitrogen and phosphorus

in the plant body and return to the soil with the litterfall of A. lebbek, D. sissoo and T. arjuna seedlings have been given in table 10.3. The concentration of these elements in the plant species studied does not significantly change with increasing age of the seedlings. When the leaves fall the nutrient contained in the foliar material is returned to the soil on release by decomposition. According to Rodin and Bazilevic (1967) the principal role in the uptake of nutrient element belongs to the green assimilating organs. This has also been proved with the help of radioactive phosphorus in the case of Buchanania lanzan (Sharma *et al.*, 1970). Kaul *et al.*, (1966) also observed the same trend in Eucalyptus seedlings.

The accumulation of mineral elements in the plant is directly related to the biomass. As the seedlings of A. lebbek, D. sissoo and T. arjuna become older, increasing amount of nutrients are stored in their bodies. The result can be compared with those of Shorea robusta and Buchanania lanzan trees (Sharma, 1971) and Acacia catechu, Butea monspersma and Buchanania lanzan seedling (Agrawal, 1971)

Large differences may occur in productivity and the distribution of nutrient of primary producers, in an ecosystem. It is true even though the ecosystems may be present in the same climatic regions and located on similar soil. According to Ovington (1968) climatic and edaphic factors affect the rate of nutrient buildup largely through their effects on woodland establishment and productivity. In the forest stand supply of water and essential elements such as nitrogen and phosphorus seems to be the most important factor affecting to

productivity of A. lebbek, D. sissoo. and T. arjuna. This is indicated by similar pattern of mineral uptake and productivity in all the three seedling.

According to steward (1960) after carbon, nitrogen is the chief element for the synthesis of biologically important compounds whereas phosphorus is involved in the structure of nucleic acid and other energy transfer processes of the cell. These elements thus play an important role in metabolic activities and hence in energy fixation process of the cell.

Plant litter falling from the woodland plants to the forest floor is normally regarded as the main rout by which nutrients circulate within the forest ecosystem. The quantities of mineral elements return annually for the soil with the litter fall and are directly dependent on the mass of the litter. The return of mineral elements with the litterfall varies widely between the seedling of A. lebbek, D. sissoo and T. arjuna. The amount of nitrogen returned to the soil with the litterfall of A. lebbek, D. sissoo and T. arjuna seedling is just similar to the young deciduous forest stand where only 16-18 per cent of the total reserves of nutrients are returned with the litter (Rodin and Bazilivic, 1967). The reason why the biomass of deciduous forests annually returns of large share of mineral elements with the litterfall than is provided by coniferous forests, where the share is 3-5 per cent (Rodin and Bazilevic, 1967) is that in deciduous forest practically all the green parts are alinated into the litterfall. As it has been shown in the result, these green parts are particularly rich in mineral elements.

The comparative values of the uptake, accumulation and return of nitrogen and phosphorus have been furnished in Table 10.3. The data revale

that in T. arjuna uptake and accumulation of nitrogen is higher than that in both of the other species.

Table - 10.3: Comparative account of nitrogen and phosphorus uptake, retention and release (mg/plant) in *A. lebbek*, *D. sissoo* and *T. arjuna*.

	<u>A. lebbek</u>		<u>D. sissoo</u>		<u>T. arjuna</u>	
	N	P	N	P	N	P
Uptake	6.660	2.916	14.848	1.493	56.859	13.774
Mineral retention						
Leaves	0.924	0.290	2.377	0.210	8.304	1.315
Stem	0.968	0.892	3.576	0.354	18.360	9.180
Root	3.328	1.456	5.670	0.643	24.700	6.175
Total	5.220	2.638	11.623	1.207	51.364	16.670
Total Mineral						
release with						
litterfall	1.440	0.278	3.225	0.286	5.495	2 104

In the last it may be concluded that the age of the plant affects the accumulation in synthesis of organic substances, which may finally affect the caloric content of plants. Although the general pattern of minerals uptake, retention and release is similar for all the three species studied but the magnitude of the process is greatly different being lowest in A. lebbek and greatest in T. arjuna seedlings.

CHAPTER - XI

SUMMARY

SUMMARY

In seed stage the embryo is protected, biological activity is at minimum level and it can withstand the extremes of environment easily. But once the germination is over, in the young seedling, biological activities like cell division, differentiation of tissues, biochemical reaction etc. are at the rapid pace. On germination the reserve food in seeds is quickly exhausted and the shoot has to meet the high food requirements for a rapid growth for the formation of leaves and development of chlorophyll, adequate sunlight, proper temperature etc., are the basic requirements for the successful establishment of the seedlings.

Thus in view of the above text present investigation deals with the germination of seed, growth analysis, biomass, productivity, energetics and mineral status of seedlings upto the age of 12 months of three forest tree species viz. Albizzia lebbek, Benth, Dalbergia sissoo, Roxb, and Terminalia arjuna, Bedd. These are the important species of deciduous forest of Bundelkhand region. The findings have been schematized in Fig. 11.1, 11.2 and 11.3.

Culture experiment were conducted in the Forest Nursery, Aata, Orai Division situated at lat. $25^{\circ} 59' N$, long. $79^{\circ} 37' E$ and about 125 m above mean sea level in Bundelkhand region, Uttar Pradesh. The study area was fully protected from all the type of biotic interferences.

Computation of water balance of the study area was made following the method proposed by Thornthwait and Mather (1955) and the ecoclimatic

Fig. 11.1 - Schematic representation of standing state of biomass, energy and minerals in different components at different age (months) of seedlings of *Albizzia lebbek*.

N and P represents nitrogen and phosphorus respectively.

Albizzia lebbek

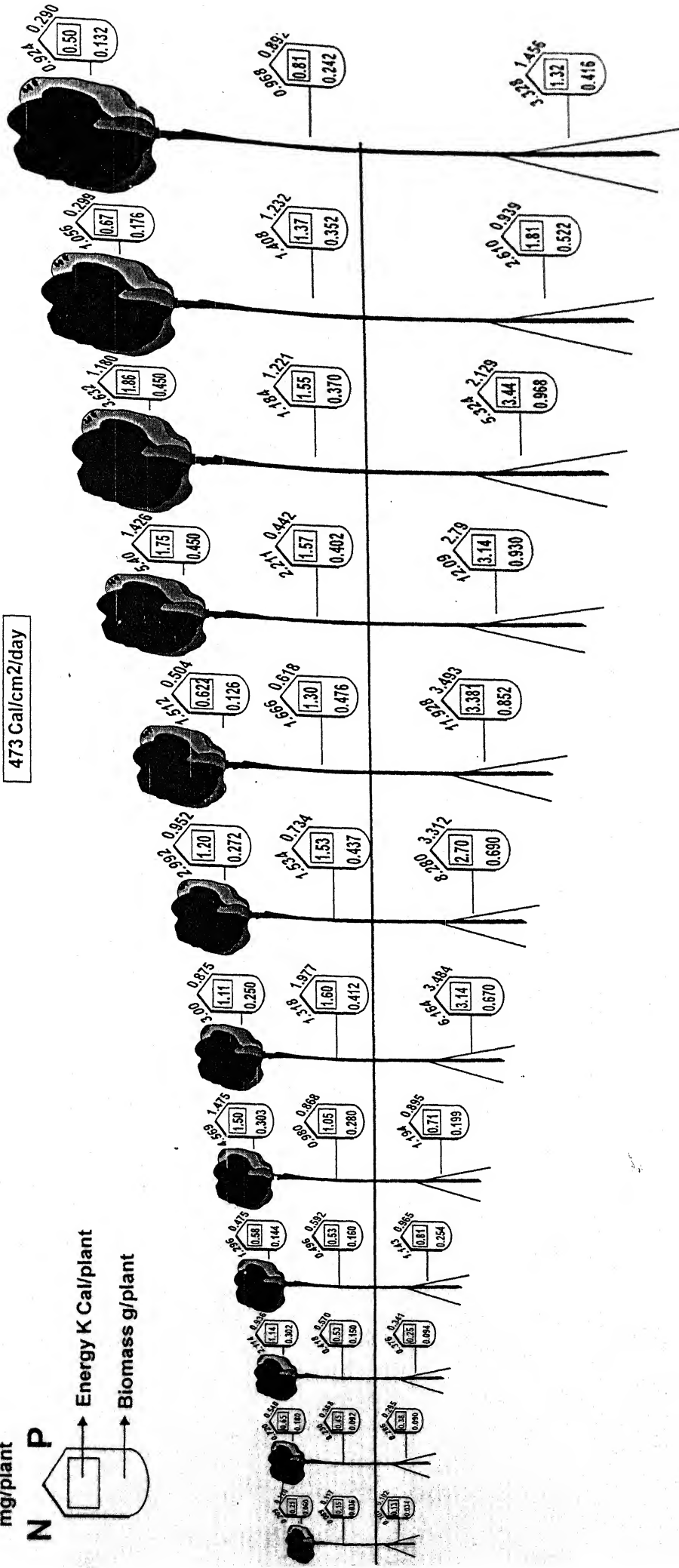
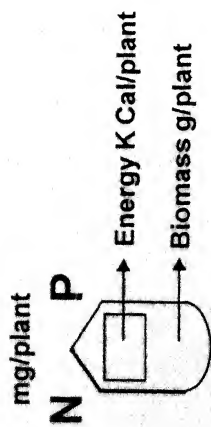
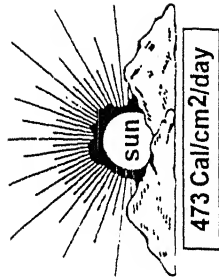


Fig. 11.2 - Schematic representation of standing state of biomass, energy and minerals in different components at different age (months) of seedlings of *Dalbergia sissoo*.

N and P represents nitrogen and phosphorus respectively.

Dalbergia sissoo

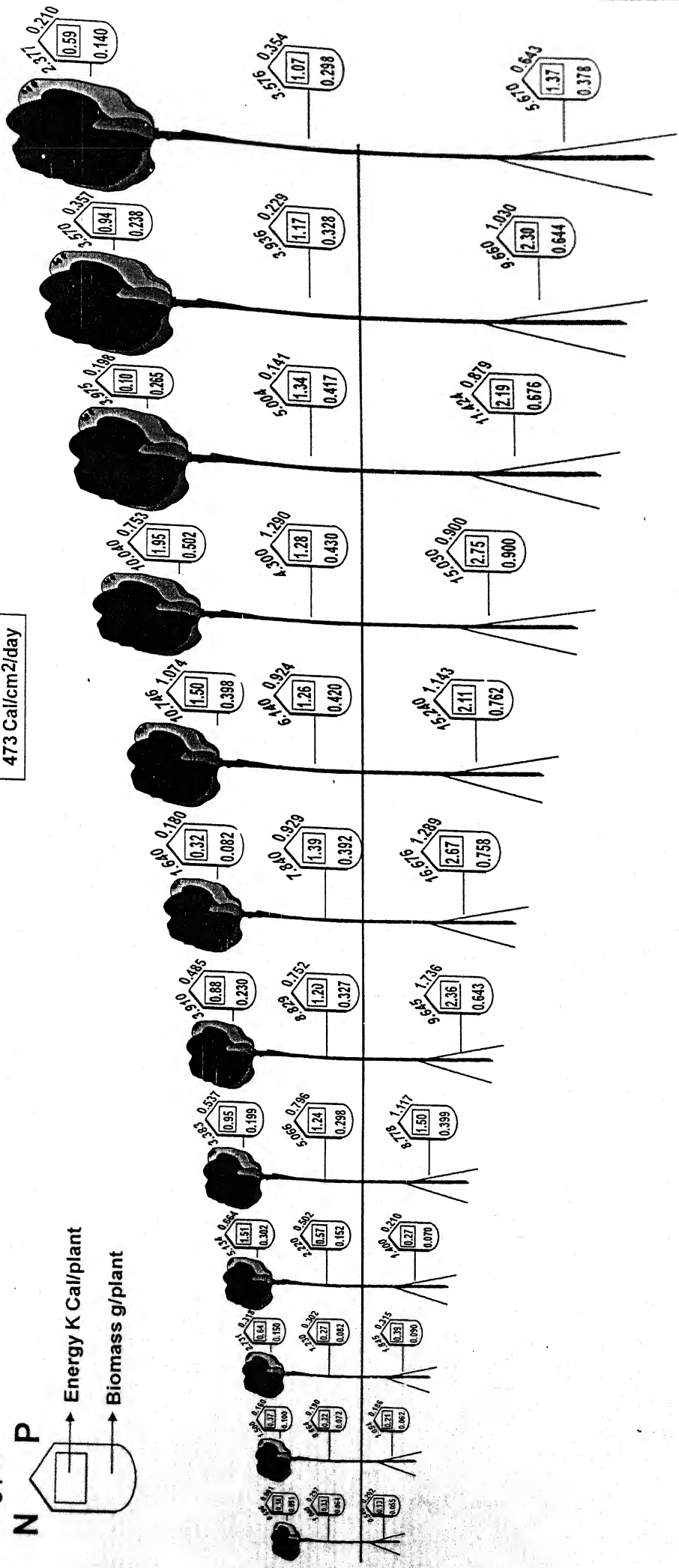
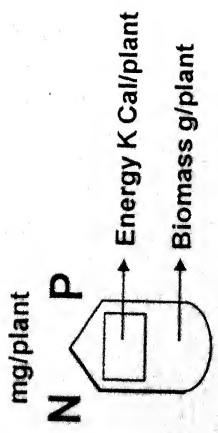
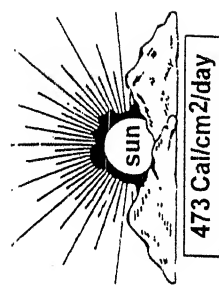
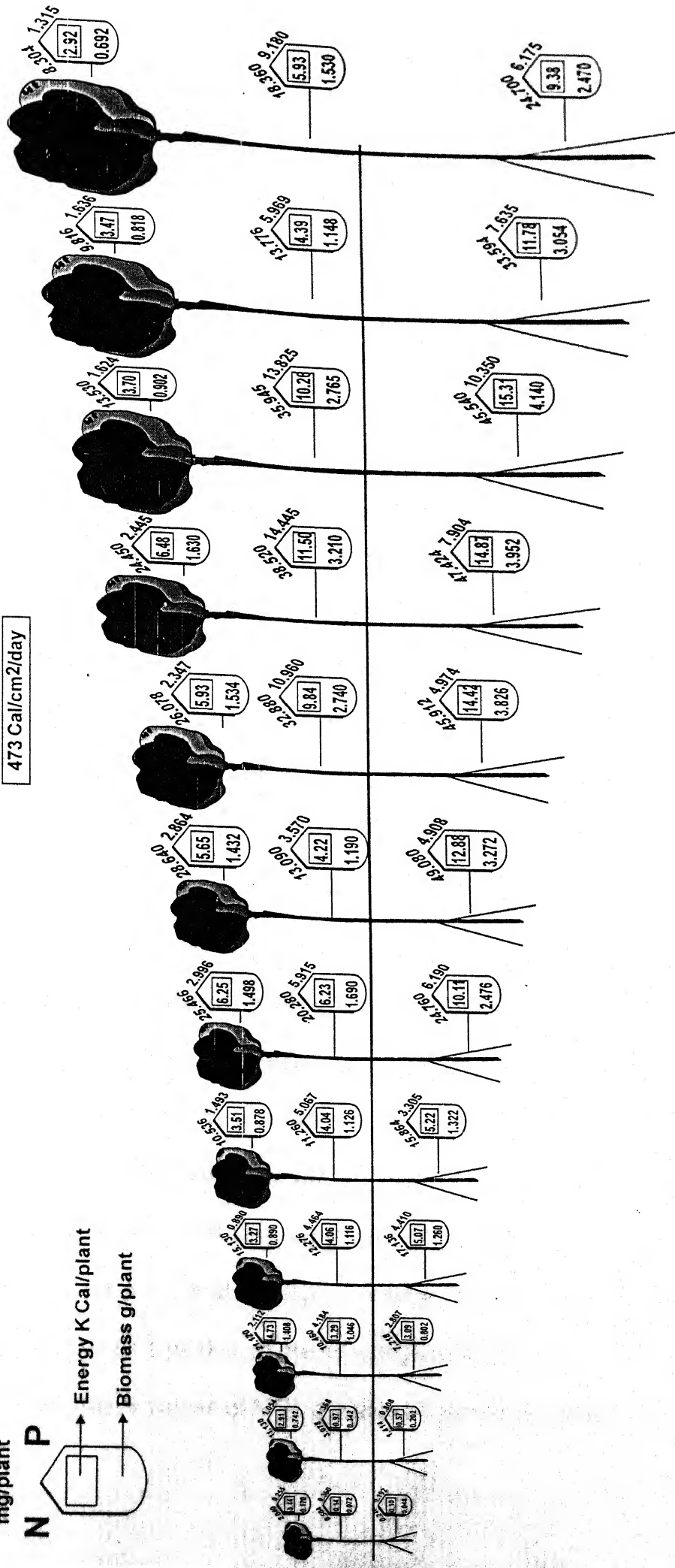
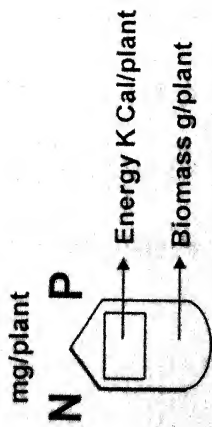
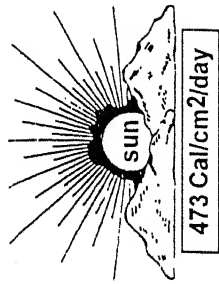


Fig. 11.3 - Schematic representation of standing state of biomass, energy and minerals in different components at different age (months) of seedlings of *Terminalia arjuna*.

N and P represents nitrogen and phosphorus respectively.

Terminalia arjuna



formula obtained as $C_1 A_3 a_2 s$ indicated a dry sub-humid climate of the study area.

The soil of the study area is slightly alkaline, pH ranges from 7.60 to 7.70 and it is pale brown in colour. Sand content is higher than other soil aggregates. Nitrogen and phosphorus percentage decreases with soil depth.

The result of germination study indicated that diurnal alternating temperature as found in nature (as in the open room) gives better germination in all the three species. The low wave length of visible spectrum (blue light) was found suitable for the maximum germination in A. lebbek and D. sissoo whereas in T. arjuna maximum germination was recorded in dark. The range of 6.4 to 7.0 pH is suitable for germination in all the species under study. It has been observed that no germination took place in strongly acidic medium (pH 2) in any of the species.

The growth analysis separates the effects of environment on dry matter production per unit leaf area. (NAR) from its effect on production of leaf area. The growth expressed as dry matter accumulation depends mainly on the efficiency of solar energy utilization by the trees. Relative growth rate (RGR), net assimilation rate (NAR) and mean leaf weight ratio (MLWR) are showing slight differences within each of the species. The RGR of T. arjuna is considerably higher than that of A. lebbek and D. sissoo. In each case NAR values rise to a peak early at the age of 3 or 4 months. Further it declines steadily. Again it gives a peak in all the seedlings when they are of the age of 8 or 9 months. Negative values of NAR are also observed. A comparison of the

values of MLWR and NAR shows that the highest MLWR had the lowest rate of NAR. Thus a reciprocal relationship between NAR and MLWR is recorded.

The dry matter production in plant parts, as well as the whole seedling increases with the age in all the three species. The total biomass (g/plant) of 12 months age seedlings of A. lebbek, D. sissoo and T. arjuna is 0.790, 0.816 and 4.692 g respectively. The dry weight of leaves increases with age of the plant and attains a peak value followed by a reduction due to litterfall.

The percentage of leaf biomass is maximum at the early age of all the three species. It ranges from 55.31 to 58.62 per cent. It decreases with age and in 12 months age seedling it remains only 16.71, 17.16 and 14.75 per cent in A. lebbek, D. sissoo and T. arjuna respectively. The ratio of the under ground and aboveground plant biomass indicates that the younger seedling contributes high aboveground biomass than done by the under ground organs but with increasing age the reverse holds true.

The rate of energy fixation by green plants is affected to some extent by the chlorophyll content. The maximum chlorophyll content of the seedlings in T. arjuna is to be 9.504 mg/plant at 9 months age but the value goes very low in A. lebbek being 1.296 mg/plant in 10 months age and in D. sissoo it is just 2.073 mg/plant at 8 months age.

The chlorophyll in mg per gram dry weight in all the three species under study shows that it differ from species to species. In D. sissoo it increases upto the age of seven months (5.512 mg/g dry weight) and then decreases. In case of A. lebbek the maximum amount of chlorophyll (5.519 mg/g dry weight)

is recorded at the age of one month and it decreases upto the age of 9 months (1.385 mg/g dry weight). In T. arjuna no definite trend is observed.

Solar energy fixation capacity of green plant is the single most important character, which regulates the metabolism of the entire ecosystem. The overall caloric value per gram dry weight differs in A. lebbek, D. sissoo and T. arjuna. It is affected by the age of the plant. The efficiency of solar energy conservation of T. arjuna is greater than D. sissoo and A. lebbek.

A. lebbek, D. sissoo and T. arjuna seedlings at the age of 12 months retain the energy of 2.63, 3.03 and 18.24 K cal/plant respectively. The addition of energy content in the soil with litterfall by A. lebbek, D. sissoo and T. arjuna is 0.480, 0.510 and 2.687 K cal/plant respectively. The storage of energy in plant, is directly related to its biomass, with which the energy in the storage organs is moved to the growing plant parts of the seedling is 61.8, 84.3 and 93.3 per cent in A. lebbek, D. sissoo and T. arjuna respectively.

The process of energy captured by primary producers depends upon the availability of mineral nutrients (Wassink, 1968). Nitrogen and phosphorus are the essential key elements needed for the synthesis of energy rich organic compounds in the plant body. Phosphorus plays an extremely important role in a variety of reactions in seed and seedlings. Indeed in a deficient supply of nitrogen, plants remain small and under such condition they are not capable of converting primary assimilates into protoplasm. The availability of these elements to plants depends upon the physical and chemical properties of the soil. Nevertheless climatic conditions and age of the plant also affect

their uptake.

Nitrogen and phosphorus stored in the seed of T. arjuna is maximum among the species studied. The total accumulation of nitrogen and phosphorus increases with the age of seedlings in all the three species, but T. arjuna seems to be more efficient. The data, at twelve months age of the seedling of A. lebbek indicate that 5.22 mg/plant nitrogen is retained in the plant body but this amount is just about ten times less than T. arjuna seedling and more than two times less than D. sissoo. The phosphorus in mg/plant is high in T. arjuna (16.670) and it goes on decreasing order in A. lebbek (2.638 mg/plant) and D. sissoo (1.207 mg/plant). Relative accumulation of these elements in component plant parts is related to their biomass.

Relative greater amount of nitrogen and phosphorus are returned to the soil with the litterfall by T. arjuna which is 5.495 mg/plant and 2.104 mg/plant respectively, in comparison of the other two species during the study period of 1999-2000.

Field observations regarding the distribution of the three tree species indicate that T. arjuna is a pioneer species which is followed by D. sissoo and A. lebbek during the successional dynamics of the ecosystem. The present investigation on their seedlings explain the sequence on the basis of their capacity to change the habitat through higher RGR value and rapid turnover of organic and mineral matter in case of pioneer species. It is, therefore, concluded that similar studies on more species may throw sufficient light on the ecosystem dynamics of the forests.

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